9.0 CUMULATIVE EFFECTS

The Council on Environmental Quality (CEQ) regulations (40 CFR §§ 1500-1508) implementing the procedural provisions of the National Environmental Policy Act (NEPA) of 1969, as amended (42 U.S.C. § 4321 et seq.) define cumulative impact as:

> "…the impact on the environment which results from the incremental impact of the action when added to other past, present, and reasonably foreseeable future actions regardless of what agency (federal or non federal) or person undertakes such other actions" (40 CFR § 1508.7).

Cumulative effects analysis recognizes that the most serious environmental impacts may result from the combination of individually minor effects of multiple actions over time, rather than the direct or indirect effects of a particular action (CEQ 1997). Cumulative effects or cumulative impacts analyses began to be conducted in the early 1980s, but only recently have these analyses been examined in terms of their importance, effectiveness, and the challenges in their conduct. The challenges in assessing cumulative impacts derive in part from (1) incomplete identification of the ecological stressors, i.e., system perturbations (Canter 1999) or actions that alter ecological processes (USEPA 1997); (2) limited data and information of suitable quality that describe the individual stressors; (3) imperfect and uncertain understanding of the potential interactions among stressors in determining cumulative ecological impacts; (4) spatial and temporal scales relevant to the overall assessment; and (5) limited understanding of the resilience of potentially affected resources to past, present, and future stress.

The CEQ has suggested frameworks for incorporating cumulative effects analyses (CEA) into the environmental impact assessment process, and steps for conducting the CEA (CEQ 1997). These frameworks are shown in Table 9-1and Table 9-2. Incorporation of CEA should begin with the NEPA scoping process, and continue throughout the descriptions of the affected environment and the environmental effects of the action. Individual steps in conducting a CEA are also tied to these three major components of the NEPA process. Three fundamental elements typically characterize CEA (Spaling and Smit 1993 in Canter 1999): 1) a cause or source of change (perturbations); 2) the process of change as reflected via the pertinent system structure or processes; and 3) the result of the change (effect).

Table 9-1. CEQ framework for conducting cumulative impact assessments (CEQ 1997).

1. Cumulative effects are caused by the aggregate of past, present, and reasonably foreseeable future actions. The effects of a proposed action on a given resource, ecosystem, and human community include the present and future effects added to the effects that have taken place in the past. Such cumulative effects must also be added to effects (past, present, and future) caused by all other actions that affect the same resource.
2. Cumulative effects are the total effect, including both direct and indirect effects, on a given resource, ecosystem, and human community of all actions taken, no matter who (Federal, non-Federal, or private) has taken the actions. Individual effects from disparate activities may add up or interact to cause additional effects not apparent when looking at the individual effects one at a time. The additional effects contributed by actions unrelated to the proposed action must be included in the analysis of cumulative effects.
3. Cumulative effects need to be analyzed in terms of the specific resource, ecosystem, and human community being affected. Environmental effects are often evaluated from the perspective of the proposed action. Analyzing cumulative effects requires focusing on the resource, ecosystem, and human community that may be affected and developing an adequate understanding of how the resources are susceptible to effects.
4. It is not practical to analyze the cumulative effects of an action on the universe; the list of environmental effects must focus on those that are truly meaningful. For cumulative effects analysis to help the decision-maker and inform interested parties, it must be limited through scoping to effects that can be evaluated meaningfully. The boundaries for evaluating cumulative effects should be expanded to the point at which the resource is no longer affected significantly or the effects are no longer of interest to affected parties.
5. Cumulative effects on a given resource, ecosystem, and human community are rarely aligned with political or administrative boundaries. Resources typically are demarcated according to agency responsibilities, county lines, grazing allotments, or other administrative boundaries. Because natural and sociocultural resources are not usually so aligned, each political entity actually manages only a piece of the affected resource or ecosystem. Cumulative effects analysis on natural systems must use natural ecological boundaries and analysis of human communities must use actual sociocultural boundaries to ensure including all effects.
6. Cumulative effects may result from the accumulation of similar effects or the synergistic interaction of different effects. Repeated actions may cause effects to build up through simple addition (more and more of the same type of effect), and the same or different actions may produce effects that interact to produce cumulative effects greater than the sum of the effects.
7. Cumulative effects may last for many years beyond the life of the action that caused the effects. Some actions cause damage lasting far longer than the life of the action itself (e.g., acid mine drainage, radioactive waste contamination, species extinctions). Cumulative effects analysis needs to apply the best science and forecasting techniques to assess potential catastrophic consequences in the future.
8. Each affected resource, ecosystem, and human community must be analyzed in terms of its capacity to accommodate additional effects, based on its own time and space parameters. Analysts tend to think in terms of how the resource, ecosystem, and human community will be modified given the action's development needs. The most effective cumulative effects analysis focuses on what is needed to ensure long-term productivity or sustainability of the resource.

[1]From: CEQ. 1997. Considering cumulative effects under the National Environmental Policy Act. Council on Environmental Quality, Executive Office of the President, Washington, D.C. 64 pages + appendices.

Table 9-2. Steps in cumulative effects analysis (CEA) to be addressed in each component of environmental impact assessment (EIA).

EIA Components	CEA Steps
Scoping	1. Identify the significant cumulative effects issues associated with the proposed action and define the assessment goals. 2. Establish the geographic scope for the analysis. 3. Establish the time frame for the analysis. 4. Identify other actions affecting the resources, ecosystems, and human communities of concern.
Describing the Affected Environment	5. Characterize the resources, ecosystems, and human communities identified in scoping in terms of their response to change and capacity to withstand stresses. 6. Characterize the stresses affecting these resources, ecosystems, and human communities and their relation to regulatory thresholds. 7. Define a baseline condition for the resources, ecosystems, and human communities.
Determining the Environmental Consequences	8. Identify the important cause-and-effect relationships between human activities and resources, ecosystems, and human communities. 9. Determine the magnitude and significance of cumulative effects. 10. Modify or add alternatives to avoid, minimize, or mitigate significant cumulative effects. 11. Monitor the cumulative effects of the selected alternative and adapt management.

[1]From: CEQ. 1997. Considering cumulative effects under the National Environmental Policy Act. Council on Environmental Quality, Executive Office of the President, Washington, D.C. 64 pages + appendices.

The Navigation Study CEA endeavored to follow the frameworks and components just described. As noted in Section 1.5.4, the study scoping process resulted in the incorporation of a cumulative effects study, which focused on the cumulative effects associated with the historical and continued operation of the 9-Foot Channel Project (WEST 2000). The final study report consists of a geomorphic assessment (Volume 1) and an ecological assessment (Volume 2). This comprehensive assessment provides a detailed quantification of historical planform (a two-dimensional picture, i.e., not including depth or elevation) changes in the Upper Mississippi River (UMR) and the Illinois Waterway (IWW) and the corresponding impacts on flora, fauna, and ecological processes. Essentially, the WEST (2000) assessment describes the cumulative effects of the existing project on channel morphology and ecology and develops predictions of geomorphic and ecological conditions for the year 2050.

The geographical extent is broadly defined by the Upper Mississippi River Drainage Basin. However, the primary impacts on resources of concern are associated with the main channel, secondary channels, and backwaters of the UMR and IWW. The pertinent time scale for assessing cumulative impacts spans approximately 110 years, and dates from 1940, when the lock and dam system was largely constructed and operational, through 2050, the end of the project planning horizon.

This chapter will briefly review the affected environment, which was described in detail in Chapter 5, describe the ecological stressors that have shaped and will continue to shape the natural and human environments of the Upper Mississippi River System (UMRS), and then consider the Navigation Study impacts, presented in Chapter 8, in terms of their cumulative effects. The final section makes recommendations based on system sustainability, and identifies a comprehensive ecosystem restoration program for significant cumulative impacts to compensate for cumulative impacts including the ongoing effects of the operation and maintenance of the 9-Foot Channel Project.

9.1 Affected Environment

9.1.1 Important Resources, Ecological Processes, and Human Communities

Chapter 5 presents a detailed description of the Upper Mississippi River Basin and the Upper Mississippi River System in terms of formation over geological time; physical, environmental, and cultural characteristics; social and economic conditions; and multi-purpose management. The chapter concludes with the identification of significant ecological processes and resources, and in particular those resources that may be affected by the proposed project. These resources, which became the focus of study for direct and indirect impacts, also form the components of the cumulative effects assessment. These resources consist of the following:

- Aquatic plants, fish, freshwater mussels, and other macroinvertebrates.
- Sediment resuspension and transport to backwaters and secondary channels.
- Floodplain forest, cultural resources sites, and other habitats of concern adjacent to the river.

The Navigation Study Cumulative Effects Study (WEST 2000) examined many of the same resources, albeit in a much more comprehensive manner, and in the context of change over time and predicted future condition. The study utilized a mix of qualitative and quantitative methods to conduct the analysis, beginning with a thorough review and compilation of pertinent existing data, including all practically available historic and contemporary mapping and photogrammetric data. Historic photographs from approximately 1930, 1940, 1975,and 1989 were used to construct patterns of change for aquatic habitats (e.g., backwaters, secondary channels, etc.) since construction of the lock and dam system, and to help forecast future geomorphic and ecological conditions through 2050.

9.1.2 Ecological Stressors in the UMRS

9.1.2.1 General

Ecological stressors result from natural events or human actions that cause a subsequent population, community, or ecosystem level response. The goal of characterizing stressors is to determine whether the resources, ecosystems, and human communities of concern are approaching conditions where additional stresses will have an important cumulative effect (CEQ 1997). Figure 9-1 illustrates a flowchart of potential ecological stressors in the UMRS. Stressors may be temporary (i.e., seasonal drought) or permanent (i.e., channelization or impoundment). In many cases, stressors serve to benefit one population or community while adversely affecting another. Generally, those occurring for a short duration at a localized site are of less concern than those occurring for an extended time over a wide geographical region.

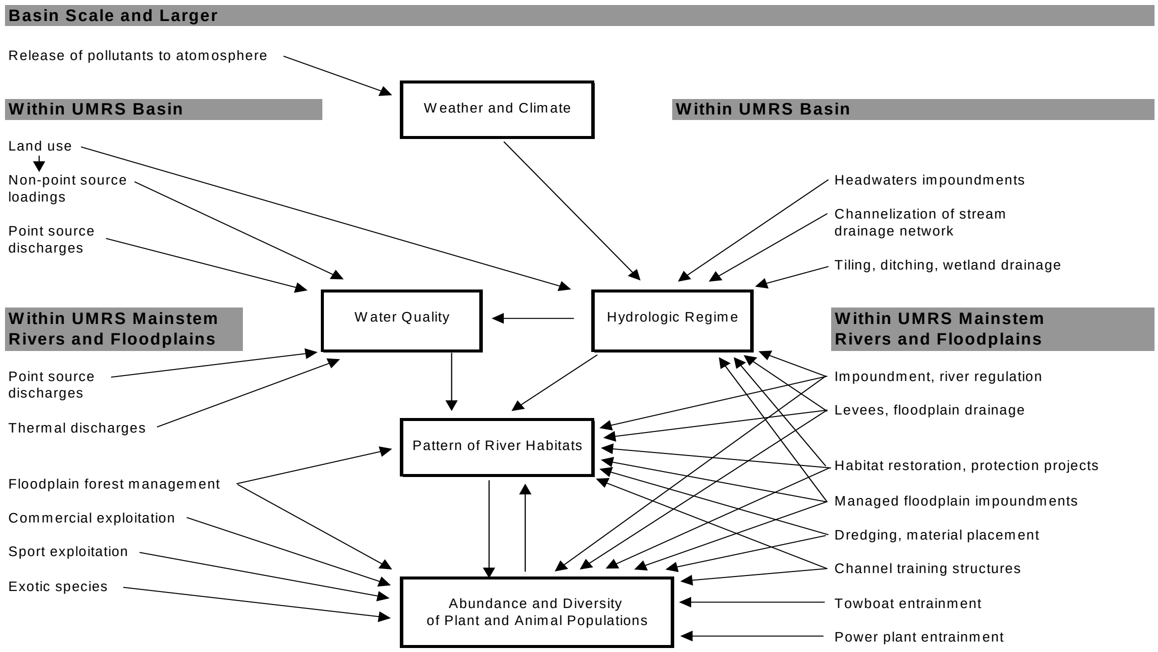


Figure 9-1. Human activities that affect the Upper Mississippi River System Environment (WEST 2000).

The ecological response to stressors is often highly variable, dependent to a large degree on the resilience or integrity of the population, community, or ecosystem being considered. As ecosystem components are stressed, resilience may be degraded and, in turn, integrity compromised. Stress effects can be synergistic or additive, and thus a multi-dimensional or cumulative analysis is necessary to account for such interactions.

Terms such as “ecosystem health” or “integrity” are becoming more common, but remain difficult to clearly define. These concepts have, however, been addressed for the UMRS in recent years. In 1994, an international conference was conducted on the topic of applying ecological integrity principles to management of the UMRS (Lubinski 1995). The conference resulted in several suggested principles for a scientifically based definition of river health. These principles were reviewed and expanded upon by Lubinski (1999), resulting in six criteria for assessing ecosystem health of the UMRS. These criteria, abbreviated, are as follows: 1) ecosystem supports habitats and viable plant and animal populations similar to predisturbance populations; 2) ability to return to preexisting condition after natural or human disturbances; 3) ecosystem is self-sustaining; 4) the river can function as part of a healthy basin; 5) an annual “flood pulse” connects the main channel and its floodplain; and 6) infrequent natural events – floods and droughts – are able to maintain ecological structure and processes. The most recent review of the approach to ecosystem management, the UMRS Environmental Science Panel (Lubinski and Barko 2003, ENV 52), affirmed past management and recommended an adaptive management for the continuing assessment and management of the system. The UMRS currently exists in various states of health; some reaches have been more extensively altered and degraded than others. This section provides a general overview of ecological stressors within the UMRS, which have tested and will likely continue to test the integrity of the UMRS ecosystem under existing and future conditions.

9.1.2.2 Land Cover/Land Use

Changes in land cover/land use show a clear gradation on the UMRS, increasing in the downriver direction. Figure 9-2 depicts presettlement and contemporary land cover in selected Upper Mississippi and Illinois River geomorphic reaches. Figure 9-3 presents an image of changes common below Rock Island and Peoria, Illinois. Agricultural development and navigation improvements are the two anthropomorphic actions that have largely transformed lands adjacent to the UMRS. For example, the logging or flooding of floodplain forests, draining of wetlands, building of levees, and plowing of prairies have caused a direct reduction in the amount and diversity of available aquatic and terrestrial habitat. Habitat loss or isolation has modified the form and function of the UMRS ecosystem, causing shifts in terrestrial and aquatic species distribution, population size, and community composition. Land use changes have generally served to fragment, limit, and simplify the various endemic species assemblages. Many of the ecological stressors described in this section are directly or indirectly associated with the changes in land cover and land use patterns that continue to dominate the basin. Several studies address the historical land cover/land use transformation process and resulting consequences (Illinois Dept. of Energy and Natural Resources 1994; USGS 1999; Nelson et al. 1998; WEST 2000; USACE 2000).

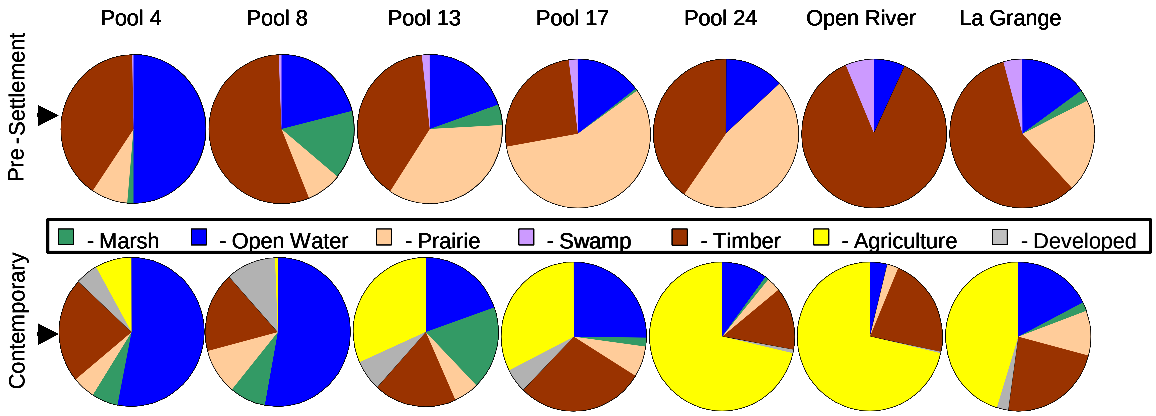


Figure 9-2. Land cover change in selected UMRS reaches between presettlement (ca. 1800-1830) and contemporary (1989) periods (USACE 2000).

9.1.2.3 Connectivity

Connectivity, in a landscape ecology context, is the degree to which habitats remain contiguous and "patchiness" is limited. It is the opposite of fragmentation or parceling of habitat into isolated patches. Modifications of habitat connectivity or patch size can strongly influence species abundance and movement patterns (Turner 1989). Korschgen et al. (1999) suggested that habitat patch distribution and abundance should be an area of further study, via "gap" analysis, on the UMRS relative to waterfowl and other migratory bird populations. Actions or disturbances that serve to restrict or eliminate connectivity often impose artificial limitations on the natural migration of water, sediments, nutrients, and aquatic species. Therefore, reductions in connectivity can impose stress on a wide variety of ecological processes or populations. The two prevalent structural limitations to aquatic habitat connectivity within the UMRS are levees and dams.

Floodplain connectivity is a significant issue because seasonal inundation of the floodplain provides for the exchange of water, sediment, nutrients, and organisms among a mosaic of habitats and thus enhances biological productivity (Sparks 1995, Bayley 1995, Junk et al. 1989). Levees generally reduce the lateral connectivity within the system by preventing the seasonal inundation of the floodplain. Approximately 40 percent of the entire UMRS floodplain has been isolated by levees (see Table 5-4), with the majority occurring below Rock Island on the Mississippi River and below Peoria on the Illinois River. Levees have provided for the conversion or isolation of approximately 1 million acres in the floodplain.

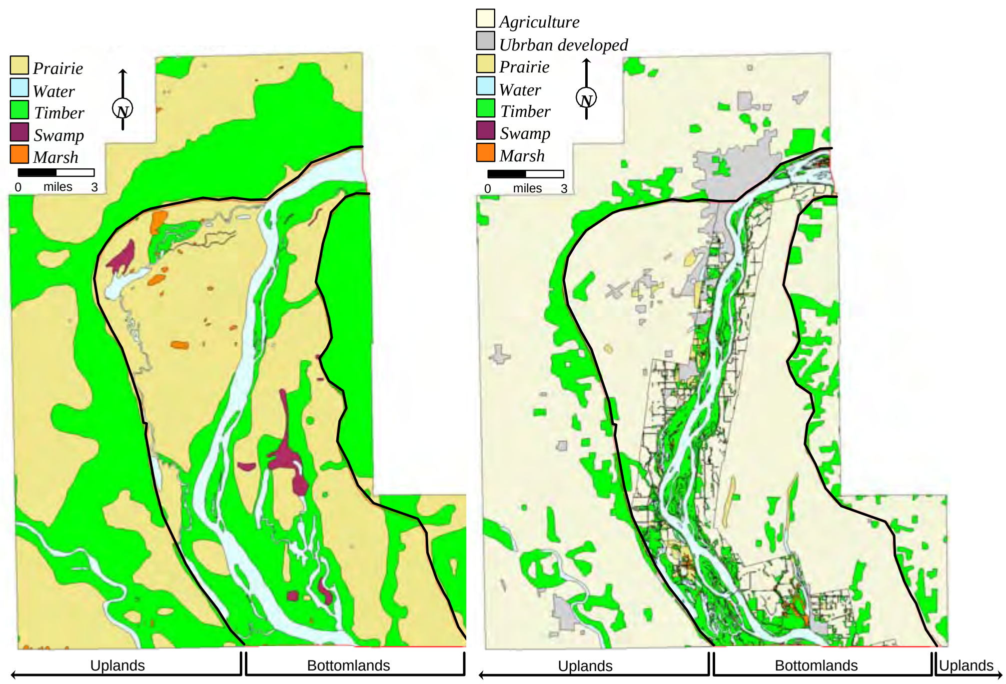


Figure 9-3. Presettlement (left image; ca. 1820s) and contemporary (right image; 1989) land cover for the Pool 17 reach of the Upper Mississippi River illustrates the changes to prairie, forest, and wetland abundance and distribution (USACE 2000). The effect is common below Pool 15.

The UMR-IWW Navigation System currently has 37 operational dams, 29 on the Upper Mississippi River and 8 on the Illinois Waterway, that reduce the longitudinal connectivity within the system by restricting the inter-pool movements of fish species. The degree to which these dams limit connectivity varies. Figure 9-4 depicts the annual percent probability (1965-95) that UMR dams are in uncontrolled condition (gates out of the water). Reduced current velocity upstream of the dams has increased rates of sedimentation, decreasing bathymetric diversity in the impounded section, backwaters, and secondary channels. The dams were not designed for flood attenuation, but rather to prevent low water levels associated with the summer drawdowns or periodic drought events. They essentially support a more stable, yet elevated, water level. Restricted fish passage can disrupt migration behavior, spawning, access to foraging and wintering areas, and may combine to limit growth, recruitment, overwinter survival, and population size. Evidence for these effects on UMR fish populations is limited, especially since fish managers have yet to be able to develop reliable standing crop estimates for any of the floodplain river fish species. Fish species most likely affected by restricted movements include lake sturgeon, paddlefish, American eel, Alabama shad, skipjack herring, blue sucker, blue catfish, northern pike, white bass, walleye, and sauger. Depending on the controlled discharge capacity of the navigation dams and the timing of fish migrations, the window of opportunity for upriver passage varies markedly between dams and fish species. The presence of multiple dams reduces the cumulative probability of successful upriver migration for long-distance migrants. Opportunity for upriver fish passage through dams is greatest during uncontrolled conditions (i.e., gates out of the water) due to the lower velocities through the dam gate openings (Wilcox et al. 2004, ENV 54). The frequency, timing, and duration that dams are in the uncontrolled condition are highly variable.

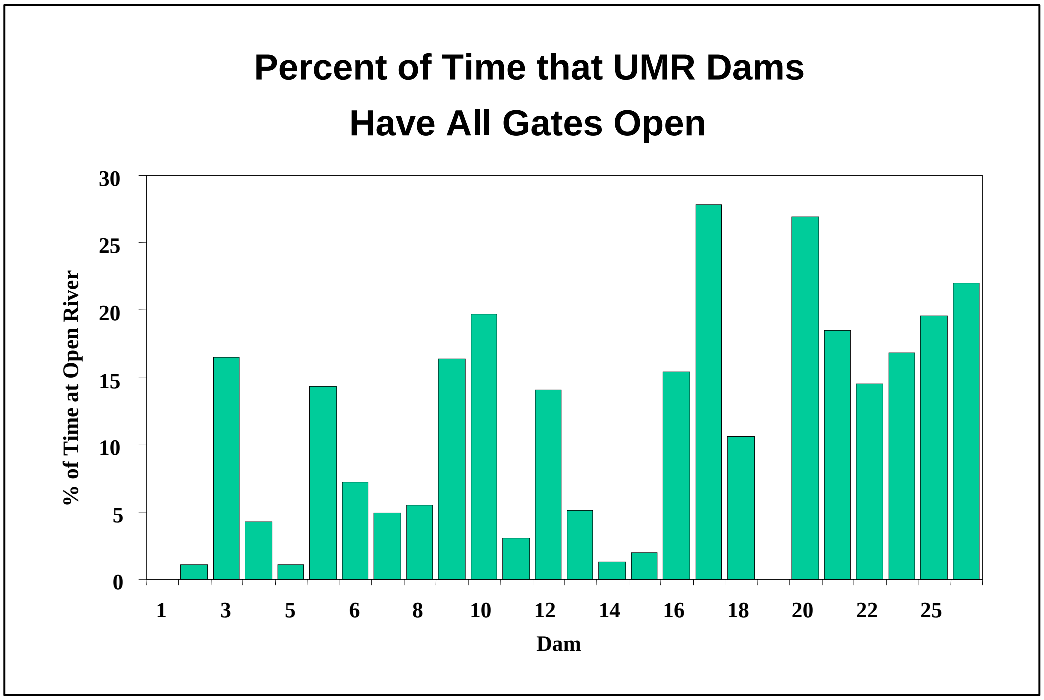


Figure 9-4. Frequency that Upper Mississippi River-Illinois Waterway System dam gates are opened with maximal potential fish passage (USGS 1999).

9.1.2.4 Channel Training Structures

Channel training structures include a variety of rock structures (i.e., wing dams, closing dams, bank revetment) designed to maintain the alignment and depth of the navigation channel and to stabilize the riverbanks. Channel training structures prevent channel avulsion (i.e., forcible separation) and the formation of new channels and islands. The net effect is considerably more boulder substrate in the river, a deeper main channel, less woody debris from caving banks, and fewer and less-frequently changing river features such as secondary channels, sandbars, and islands. Closing structures decrease water flow into secondary channel or backwater habitats, which often results in rapid filling with sediments during floods and isolation during low water events. As a result, channel training structures have artificially stabilized the processes that serve to modify habitat. Although the primary purpose of such structures is to preserve or enhance the navigation channels, they have also been used effectively to provide some ecological benefits. Newer structures, such as bendway weirs, chevron dikes, and other innovative, environmentally sympathetic designs, have been developed recently and are being studied to assess their effectiveness to maintain navigation and to determine their habitat value (e.g., feeding substrate for invertebrates, low-velocity shelter for fish). Older structures have also been redesigned, mostly by notching, to increase flow in the dike field and subsequently increase habitat diversity.

9.1.2.5 Impoundment

The construction of the locks and dams caused the permanent inundation of extensive portions of the floodplain in some areas (Figure 9-5) and created a series of slackwater "pools." The extent of floodplain inundation is generally greater in the downstream portions of the navigation pools, creating open impounded areas in many, and leaving the upper portions of the navigation pools in a relatively natural riverine state. High elevation features of the floodplain (e.g., natural levees, terrace remnants) became islands upon inundation. Secondary and tertiary channels, which were only seasonally flowing prior to impoundment, became continuously flowing channels. Littoral processes of shoreline erosion and sediment transport have greatly modified the lower parts of the navigation pools since impoundment. The deeper, submerged channel areas have filled with sediment, and many islands were eroded away. Extensive impounded areas in the lower parts of the navigation pools have lost much of their bathymetric diversity and now have relatively uniform depths.

The increased water levels following impoundment formed extensive shallow aquatic and wetland habitat in the formerly seasonally inundated floodplain. The higher and continuous water levels in the floodplain soil profile resulted in a modified floodplain forest that is now dominated by mostly flood-tolerant trees such as silver maple (*Acer saccharinum*). The higher groundwater table has restricted the rooting depth of trees growing in the floodplain, making them more vulnerable to wind throw. Wind throw of trees has accelerated island and shoreline erosion processes in portions of navigation pools where the floodplain surface is near the water level, primarily in the downriver half of the navigation pools.

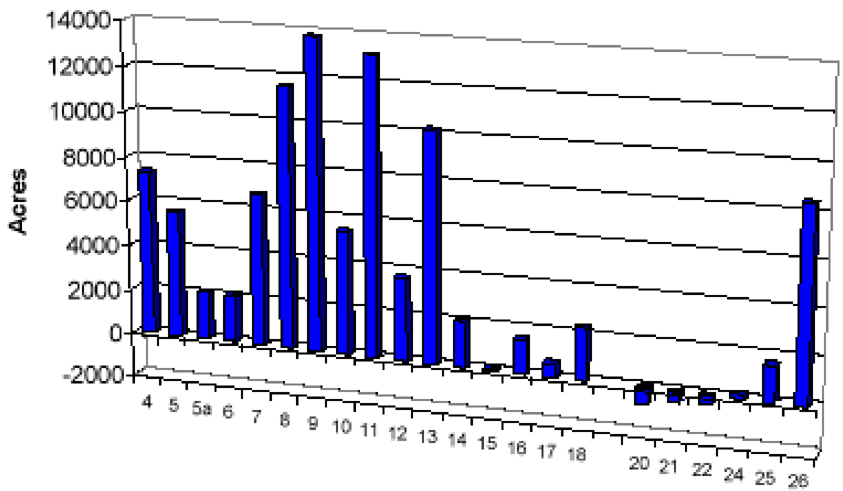


Figure 9-5. The change in acres of open water in Upper Mississippi River pooled reaches attributable to impoundment.

9.1.2.6 Altered Hydrologic Regime

The ecological diversity and integrity of large floodplain rivers is closely associated with the hydrologic regime. The seasonal flood pulse and intermittent periods of low flow strongly influence the habitat structure, trophic base, and biotic interactions (Sparks 1995). The stressors discussed in the preceding paragraphs have acted to suppress the hydrologic regime of the UMRS by restriction of the seasonal flood pulse, elimination of the intermittent low flows, and restriction of channel migration. Within the last decade, several scientific publications have further increased awareness and understanding of the adverse environmental effects of a restricted hydrologic regime (Junk et al. 1989; Sparks 1995; USACE 1995b; Wiener et al. 1998; USGS 1999; see also Landwehr et al. 2004, ENV 53).

9.1.2.7 Contaminants

Contaminants, which may include heavy metals, pesticides, or synthetic organic compounds, degrade water quality and can accumulate in sediments and biota. Section 5.2.6 summarizes several important studies on the subject, many specific to the UMRS. Examples of studies documenting the historical trends in contamination within the UMRS include Fremling and Claflin 1984, Sparks 1984, Meade 1995, USGS 1999, and WEST 2000. Through most of the 20th century, the UMRS was subject to unrestricted disposal of raw sewage and industrial wastes. Large areas downriver from major metropolitan areas were rendered inhospitable for many native species due to anoxic conditions or high concentrations of ammonia, heavy metals, and polychlorinated biphenyls (PCB's). Since the mid- to late-1970s, water and sediment quality has greatly improved, attributable primarily to adoption of national water quality standards and enforcement of the 1972 Clean Water Act, requiring the elimination and/or secondary treatment of point sources of municipal and industrial waste. Despite these gains, the UMRS remains subject to contamination from agricultural, industrial, municipal, and residential sources, with most input characterized as non-point in nature. Agriculture is the dominant land use in the basin, and chemical fertilizer and herbicide application rates are among the highest in the Nation (Meade 1995).

Contaminants can have chronic or acute (lethal) effects, depending on the rate of exposure and the particular organism affected. Persistent exposure to these substances makes it likely that they will accumulate within the tissues of aquatic organisms. Bioaccumulation is possible in fish species that are continually exposed and feed upon contaminated aquatic insects. The accumulation of toxins in fish occasionally requires issuance of consumption advisories, especially for bottom-feeding fish with high body fat content. As benthic filter-feeding organisms, freshwater mussels are particularly vulnerable to contaminants dissolved in water, associated with suspended particles, and deposited in bottom sediments. Thus, freshwater mussels can bioaccumulate contaminants to concentrations that greatly exceed those dissolved in water (U.S. Fish and Wildlife Service, unpublished data). Other species that feed upon these contaminated organisms would in turn be exposed to magnified concentrations of contaminants. For spawning fish, contaminated sediments may expose their eggs or juveniles to toxic substances.

The central region of the Upper Mississippi River Basin (i.e., the Corn Belt) is the greatest contributor of nitrogen and phosphorus compounds to the Gulf of Mexico hypoxic zone (Figure 9-6). The hypoxic zone is a large region of poor water quality at the Mississippi River Delta. The ecological and economic impacts are substantial (Interagency Hypoxia Committee 2000).

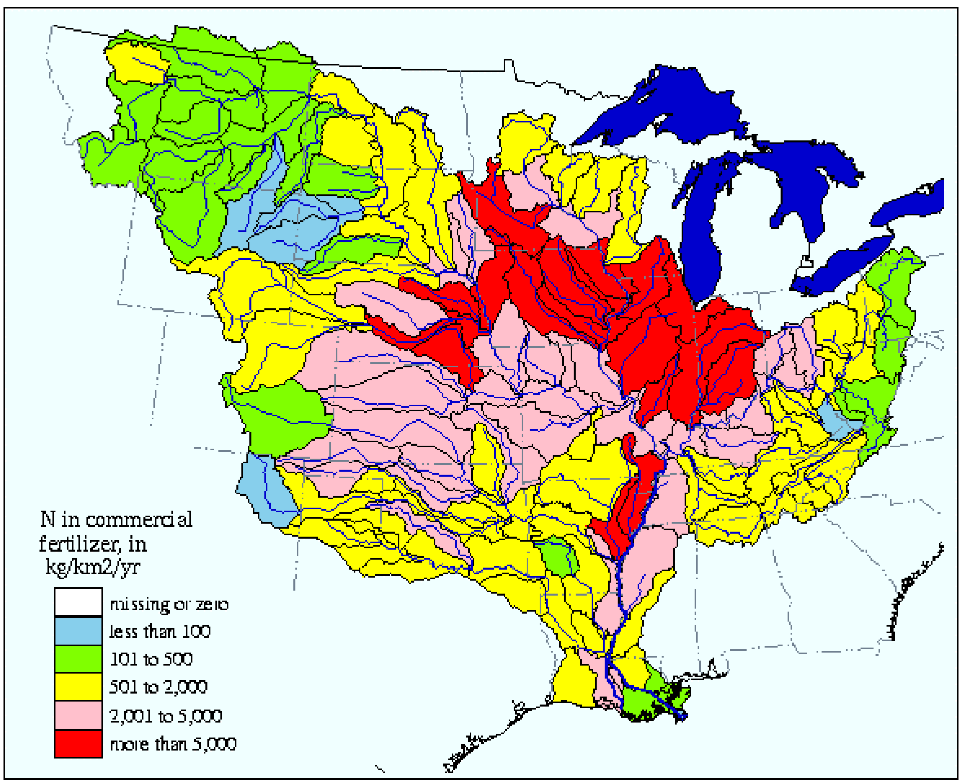


Figure 9-6. Mississippi River sub-basin nutrient contributions to the Gulf of Mexico hypoxic zone.

9.1.2.8 Sedimentation

Sedimentation is likely to continue to be one of the most significant threats to the integrity and long-term health of the UMRS ecosystem. Given the dominance of agriculture in the basin, upland runoff of sediments remains widespread, though more conservation-minded farming practices in the last 10 to 15 years have apparently led to a general decrease in sedimentation rates (WEST 2000). The UMRS is particularly vulnerable to sedimentation, not only because it drains such a vast land area but because its system of locks and dams and leveed floodplain inhibit the river's natural sediment transport and distribution capacity. Sediment deposition in off-channel areas ultimately results in a loss of habitat diversity, which in turn affects species abundance and diversity. In addition to adverse impacts in backwaters, sediment also accumulates in the main channel of the river, requiring significant annual expenditures on dredging to maintain the 9-foot navigation channel.

9.1.2.9 Resource Consumption

Consumptive exploitation of aquatic resources for recreational and commercial purposes can limit the abundance and distribution of certain UMRS species. Such utilization primarily affects fish, waterfowl, and mussels that have substantial recreational or commercial value. Over-exploitation is certainly less common than it was during the first half of the 20th century, before the era of science-based resource management, but illegal harvest of valuable resources such as paddlefish and sturgeon caviar or freshwater mussels can still be a problem. The five UMRS States have for some time individually and collectively monitored and regulated the impact of recreational and commercial harvest of fish, waterfowl, and mussels through the sale of licenses, established harvest seasons, and restrictive size/bag limits. There is no reason to believe that these efforts will cease, and it will be important for agencies to increasingly consider consumptive use in light of other cumulative stressors such as pollution or exotic species.

9.1.2.10 Introduced Exotics

As it affects interspecific competition among UMRS flora and fauna, the introduction, dispersal, and proliferation of numerous exotic species is having an increasing impact. Exotic introductions have resulted from maritime and interstate commerce, recreational boating, sport fish stocking, and accidental releases associated with the aquaculture industry, bait business, and horticultural practices. In many cases, the impact of exotic species introduction and proliferation can extend beyond a specific native species or population to the entire ecosystem. To date, control practices for exotic species have been largely unsuccessful in the UMRS. Among the introduced exotics discussed in Section 5.2.7.9, the common carp and zebra mussel are perhaps the two species that have had the most significant impact, but the impacts of the Asian carp have probably not yet been fully displayed. Studies have been initiated or are planned to assess and evaluate control measures for zebra mussels and other recently introduced exotic species such as the round goby and Asian carp. It has been suggested that commercial navigation traffic facilitated the spread of the zebra mussels upstream from the Illinois Waterway. The distribution of other exotic fish species could expand if fish passage measures are pursued at dams on the system.

Recently acclimated Asian carp (bighead carp (*Hypophthalmichthys nobilis*) and silver carp (*Hypophthalmichthys molitrix*)) pose potentially significant threats to the system. The fish were introduced in southern aquaculture management and have migrated widely through the system. Lock and Dam 19 has, until now, blocked significant movement upstream on the UMR. There is great concern over their migration into the Great Lakes through the IWW. Currently, Asian carp have become a significant part of the total fish biomass in many areas. They are unmarketable and impede the ability of commercial fishers to catch marketable species.

9.1.2.11 Riverside Development

Industrial, municipal, and other types of development in and along the UMRS is likely to increase in response to an ever-increasing human population. Induced human development often creates a "ripple effect" which ultimately affects other ecosystem components. During early settlement of the UMRS, large areas of undisturbed woodland, wetland, and prairie were converted for agricultural production or other types of utilization. Current development pressures come in the form of conversion of the last remaining areas of these habitats for commercial, industrial, or housing development. Direct and indirect effects of such development include habitat alteration or loss, withdrawal from or discharge into the river, and increased runoff from impermeable surfaces. Withdrawal of river water has been identified as a source of mortality for planktonic life forms such as phytoplankton, zooplankton, ichthyoplankton, and drifting benthic macroinvertebrates (WEST 2000). Discharge of thermally, organically, or chemically enriched waters from industrial/municipal secondary treatment facilities continues to be a major concern. Withdrawal and discharge demands are likely to increase. The Federal Energy Regulatory Commission (FERC), U.S. Environmental Protection Agency (EPA), and State resource agencies have primary responsibility for the regulation, monitoring, and enforcement of withdrawals and discharges. In most cases, guidelines have been established, permits are issued, and periodic inspections are conducted to evaluate compliance.

9.1.2.12 Commercial Navigation

Commercial barge traffic, in aggregate, has increased steadily on the UMRS since 1950. Barge traffic itself, and activities associated with the operation and maintenance of the 9-foot navigation project, may impose a variety of stressors on the UMRS ecosystem (Sparks et al. 1979; Rasmussen 1983; WEST 2000). Many of these stressors have been discussed in detail in the preceding chapters. In general, stressors commonly identified or attributed to commercial navigation traffic include physical forces (i.e., shear, pressure), wave induced shoreline erosion, drawdowns, entrainment mortality of planktonic life forms, and sediment resuspension. The physical effects and ecological risk assessments summarized in Section 8 are among the most aggressive ever completed. In addition, less common stressors such as periodic accidents, chemical or petroleum spills, or disruptive noise levels associated with commercial navigation are also considered in the cumulative assessment.

The primary purpose of the UMR-IWW Navigation Feasibility Study was to evaluate the need for improvements to the existing system to accommodate a predicted future increase in commercial barge traffic. Subsequently, the primary focus of this PEIS is to evaluate the impact of the proposed improvements, especially as they pertain to increased commercial barge traffic. A comprehensive and detailed assessment of the environmental consequences of commercial navigation traffic is presented in Chapter 8 of this document.

9.1.2.13 Bank Erosion

Bank erosion is a natural process occurring along every river, stream, and creek. A natural river system meanders across its floodplain through the processes of bank erosion and deposition. This meandering, in turn, produces different types of aquatic habitats. If the natural process of bank erosion is halted, the dynamic cycle of habitat creation and loss would also cease. In severe cases, bank erosion can threaten the loss of cropland, forest, or riparian zones, as well as residential areas or municipal facilities. Such losses can adversely affect plant and animal uses of aquatic and terrestrial bankline areas, cultural resources and historic properties located adjacent to the bankline, and human uses of bankline areas. In addition to direct impacts to bankline areas, erosion may also have indirect impacts, such as contributing to sedimentation-related problems, and affecting recreational uses and aesthetic qualities of the river. The physical effects assessments summarized in Section 8 have contributed significantly to our understanding of these processes.

9.1.2.14 Dredging and Material Placement

Dredging and material placement are routine maintenance activities carried out by the Corps for the purpose of ensuring adequate depth for commercial navigation traffic. WEST (2000) provides a detailed history of the Corps dredging operations in the UMRS and addresses the impacts of dredging and material placement. The issue has long been a subject of natural resource coordination, which over the years has led to the development of Programmatic Memoranda of Understanding between the Corps and coordinating agencies (USACE 1996a, USACE 2003b). An interagency team in the Rock Island District recommended and conducted investigations of dredging and dredged material disposal impacts on sediment transport, terrestrial vegetation succession, freshwater mussels, benthic macroinvertebrates and fishes between 1997 to the present to further understand the issue. An interim report (MACTEC 2003a) summarizes the progress to dates. The results indicate little long-term impact from dredging and documents plant community response to material placement over many years. The following paragraphs will provide a general overview of maintenance dredging activities and their respective role as ecological stressors.

Available records indicate that dredged material has been placed on approximately 8,531 acres of UMRS aquatic and floodplain habitat. This area is approximately 0.9 percent of the non-agricultural and non-urban UMRS aquatic and floodplain area (WEST 2000). The total area where dredged material has historically been placed could be more than double the area than the available records indicate, given that dredging has been conducted since the late 1860s, and much of the area between wing dams was filled with dredged material.

Dredging results in a temporary and localized increase in downstream suspended solids concentration. However, dredging does not add significantly to ambient suspended solids concentrations in the UMRS (WEST 2000). Over 90 percent of the material dredged from main channel dredge cuts on the UMR is sand-sized material or larger, carrying very small concentrations of contaminants (e.g, heavy metals and organics). Contaminants are primarily adsorbed to finer silt and clay sized particles that typically are found in lower velocity areas downstream of metropolitan areas. On the Illinois River, much finer and more contaminated material is dredged than from the UMR. Although no detailed analysis has been conducted, it is believed that channel maintenance dredging mobilizes only a small fraction of the sediment contaminants in the UMR and IWW (WEST 2000).

Dredging disturbs main channel habitat, disrupting resident benthic macroinvertebrates and temporarily leveling the dune and swale bed forms (“sculpted” areas on the bottom, formed by hydraulic forces; they provide protected resting areas for some fish). However, channel bed forms reform rapidly. Moreover, most main channel dredge cut areas have unstable sand substrate that supports few species of mussels or other macroinvertebrates (MACTEC 2002, 2003b). Benthic macroinvertebrates recolonize disturbed riverbed areas through downstream drift, but may take at least one, and in the case of unionid mussels, several growing seasons to recolonize to predisturbance densities.

Placement of dredged material in shallow aquatic, wetland, and floodplain terrestrial areas changes habitat conditions at all but routinely used dredged material placement sites. Existing substrates, vegetation cover, and associated organisms are buried with washed sand. The rate of flora and fauna recolonization is dependent on a variety of factors (WEST 2000). However, this process is typically slow as the resulting sand deposits are generally unfavorable for recolonization by plants. Locations for dredged material placement vary by Corps District, but the general trend is toward placement out of the floodplain to minimize reintroduction of material, as well as maximize beneficial uses, such as island construction.

9.1.2.15 Recreational Boating

Recreational boating traffic affects the river environment in several ways, including noise, effects on water quality, sediment resuspension, effects on aquatic plants, disturbance of wildlife, bank erosion, disturbance of fish spawning, displacement of fish from shallow areas, fish entrainment mortality, and socioeconomic effects (Johnson 1994). The effects of recreational boating traffic on sediment resuspension and aquatic plants were examined in this study using an ecological risk assessment approach (Appendix ENV-J). A detailed assessment of the effects of recreational boating is included as Appendix ENV-J. In considering the effects of recreational boating traffic in a cumulative impacts context, this section presents a summary of these effects and their relationship to other ecological stressors, in particular commercial navigation.

9.1.2.15.1 Assessment Approach

The ecological stressors associated with recreational boating are primarily the hydraulic and acoustical disturbances (e.g., wake waves, propeller jet, noise) produced by passing boats, and the secondary effects of these disturbances such as sediment resuspension and bank erosion. The intensity and the spatial and temporal occurrence of these stressors are related directly to boating traffic. A recreational boating traffic forecasting and allocation model, a navigated areas Geographic Information System (GIS), an on-water survey of the UMRS recreational boating fleet, field experiments of wake wave generation and sediment resuspension, and literature review were done to characterize ecological stresses imposed by recreational boating traffic and to characterize risks (Appendix ENV-J). For this analysis, five vessel classes were differentiated: jet ski, fishing boat, medium powerboat, large cruiser, and houseboat.

The boating traffic forecast and allocation models, and the navigated areas GIS, provided the initial conditions of passage events/day/boat class/area that drive the hydraulic effects models for wake waves and sediment resuspension. Data on sediment concentrations were used as input to models simulating effects on aquatic plant growth and reproduction. The wake wave estimates by vessel class, the navigated areas GIS, and the bank erosion GIS were used to identify areas vulnerable to accelerated bank erosion. Estimates of the water entrained through recreational boat propellers were used to assess the relative impact of recreational boats on entrainment losses of fish.

Many unknown or poorly quantified factors may ultimately influence future recreational boating levels on the UMRS. Some of these factors include the future conditions of infrastructure that supports recreational boating on the rivers, and the overall environmental quality of the rivers and adjacent public lands. Other factors include social and economic conditions. Unconstrained traffic growth projections were made, assuming that access facilities, traffic intensity, and natural resource/economic conditions would not limit growth of boating activity on the UMRS.

The total projected growth in boating trips from the year 2000 to 2050 is 19.6 percent for the UMRS as a whole, ranging from 16.0 percent for the Mississippi River (Rock Island Corps District) to 22.3 percent for the Illinois River. These system-wide figures compare very closely with the U.S. Forest Service's nationwide regional demand projections for powerboating (English et al. 1993). In that study, powerboating was projected to increase by 20 percent from 1987 to 2040 in the North region (which includes the five States bordering the UMRS plus 15 other Great Lakes and East Coast States). However, the approach taken for the UMRS suggests that sub-regional growth is expected to vary substantially. Pool-level growth projections for the UMRS range from approximately 4 percent to over 40 percent across the system. The major portion of the projected growth is expected to occur in a few concentrated areas near metropolitan areas.

9.1.2.15.2 Areas Navigated by Recreational Boats on the UMRS

A GIS database of areas navigated by the different classes of recreational boats throughout the UMRS was developed through a series of workshops with people familiar with recreational boating use in their respective reaches of the system (Rust 1996a). Navigated areas were identified for each class of recreational boats, and identified as high-, medium-, or low-use areas relative to each navigation pool and river reach. Additional maps for seasonal use by vessel class were prepared for pools where the local experts identified seasonal (i.e., spring, summer, fall) differences in the spatial distribution of boating activity.

9.1.2.15.3 Allocation of Trips/Day and Vessel Passage Events/Day to Navigated Areas

The estimated numbers of boat trips per day by boat class in each navigated area throughout the UMRS were incorporated into a GIS database. This was accomplished by allocating the trips/pool/day/boat class across all the navigated area polygons in a pool for each boat class, to the high, medium, and low use area polygons following a 60 percent, 30 percent, and 10 percent allocation formula, respectively. The number of vessel passage events per day past any shoreline point was estimated by calculating distance traveled, using navigated polygon length (longest axis), information on the duration of boat trips, the amount of time spent operating on the water (from previous studies of boating on the UMRS), and the average operating speed of each boat class, as observed in the 1996 survey (Rust 1996b).

By combining the information described above, an average boat trip involves active time on the water of about 3 hours. Average active time and average operating speed (see below) were used to estimate distance traveled. Distance traveled and navigated area polygon length were used to estimate number of boat passage events per day for use in calculating sediment resuspension by boat wake waves in near-shore zones (see below).

After evaluation of the literature and the available data, it was determined that a predictive model for each vessel class was beyond the needs and the scope of the Navigation Study. Predictive wake wave models typically are based on the wave formed by a single vessel moving at a constant speed at a certain distance from the sailing line. A wide range of recreational boat hull types and operating speeds occur on the UMRS, and they do not follow distinct sailing lines. With these considerations, a table of maximum expected wave heights at distances from the sailing line for each class of recreational vessel was developed for use in conjunction with the navigated areas GIS, instead of a more detailed numerical model.

Recreational powerboats typically generate a series of about 12 wake waves during each passage event, of which the third wave usually has the maximum wave height. Recreational boat wake wave “trains” typically pass in about 24 seconds. In contrast, commercial tows generate wake wave trains that last about 7 minutes with 200 waves (Appendix ENV-J). These characteristics are typical for individual vessel passage events, and describe single wake wave trains. On the UMRS, most boat wake waves occur as single vessel passage events, except at peak times (e.g., holidays or weekends) in a few high-use areas.

9.1.2.15.4 Hydraulic Disturbances by Recreational Traffic

9.1.2.15.4.1 Sediment Resuspension

Wake waves from recreational boats can resuspend river bottom sediment as they travel through shallow water to reach shore. Resuspended sediment is maintained in suspension by turbulence in the water. Coarser particles settle out quickly, while finer particles remain in suspension longer. A numerical model was developed to simulate wake wave-induced sediment resuspension (Knight et al. 2000b, ENV 43).

9.1.2.15.4.2 Bank Erosion

An analysis was performed to assess correlation between locations of observed erosion with estimated wave heights produced by recreation craft in those areas. Approximately 57 percent of the unprotected main channel bankline was classified as moderately or severely eroded in areas where recreation craft produce up to 40-centimeter-high wake waves, whereas approximately 20 percent of this unprotected main channel bankline was classified as stable. Based on the results of this analysis, there appears to be a positive relationship between the height of waves generated by recreation craft reaching the bank and the occurrence of bank erosion along the main channel borders of the UMR.

Banklines vulnerable to erosion by recreational boat wake waves were identified according to a high/medium/low classification scheme, similar to that used in the bank erosion study and the backwater sedimentation study that was used to assess the potential effects of increased commercial navigation traffic. The classification was based on boat wake wave heights reaching the banklines.

Large cruisers operating within 300 ft of the bankline are the class of recreational vessels considered to produce the highest potential for bank erosion. Medium powerboats operating within 300 feet of the bankline or large cruisers operating 300 to 500 feet from the bankline are considered to pose a medium potential for bank erosion. All other vessel types are considered to pose a low potential for bank erosion, regardless of the distance at which they are operating from the shoreline (the next highest wave height was 16 centimeters for fishing boats within 100 feet).

The actual rates of bank erosion produced by recreational vessels are directly related to the traffic intensity. Banklines with a high potential for erosion that occur in areas with high boat traffic rates are probably eroded faster than in low traffic areas. Johnson (1994) found high rates of bank erosion in a UMR main channel reach with high recreational boat traffic rates, and much lower bank erosion rates in a nearby secondary channel that carries less boat traffic.

9.1.2.15.4.3 Propeller Entrainment of Water

The amount of water entrained through recreational boat propellers was estimated to compare to the amount of water (and fish) entrained through commercial towboat propellers. The amount of water entrained through the propeller is related to the propeller diameter, the pitch (distance the propeller would advance through the water in one rotation without slipping), and slip (the percent loss of forward travel due to friction of the hull and propeller with the water) (Table 11 Appendix ENV-J).

The existing (year 2000) and forecast (year 2040) recreational boating traffic estimates by pool and boat class, average on-water trip length from Carlson et al. (1995), and average observed on-water operating speeds (Rust 1996b) were used to calculate the total miles traveled by each class of boat during the April through August fish spawning season. An industry estimate (J. Bierman, Polaris Industries, Spirit Lake, Iowa, personal communication) was used to estimate the total amount of water entrained by personal watercraft. The estimates of miles traveled were multiplied by the typical water entrainment rates for each boat class to estimate the total amount of water entrained (Table 12 Appendix ENV-J).

Examination of the estimates summarized in Table 13 in Appendix ENV-J suggests that recreational vessels entrain a volume equal to approximately one-third (0.32) of the volume entrained by commercial vessels navigating the Upper Mississippi River in the year 2000. The recreational vessels entrain nearly one-sixth (0.15) of the volume entrained by commercial vessels on the Illinois Waterway. In the year 2040, the corresponding fractions are 0.34 for the Upper Mississippi River and 0.12 for the Illinois Waterway. These results indicate that recreational vessels appear to entrain volumes similar in magnitude to volumes entrained by the commercial vessels on the UMR-IWW.

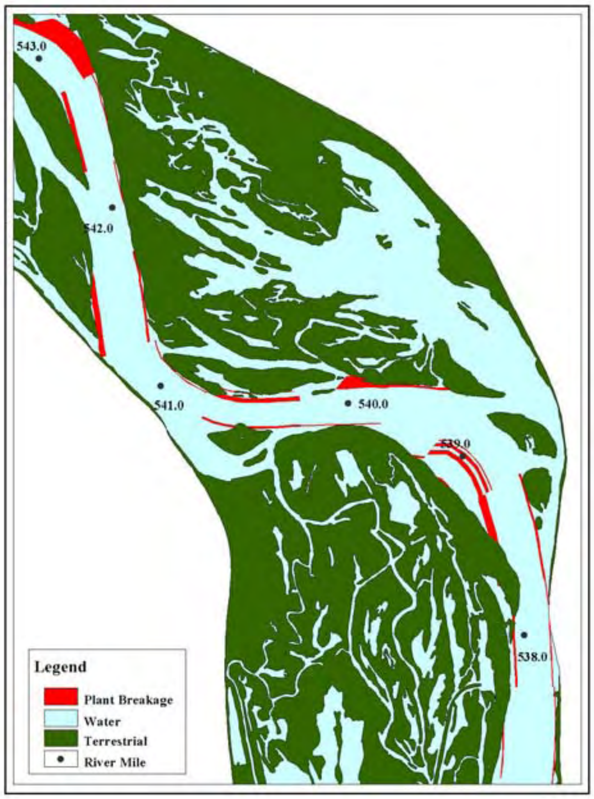
9.1.2.15.5 Ecological Effects

9.1.2.15.5.1 Effects on Aquatic Plants

Recreational boaters navigate in the main channel, in secondary channels, and in backwater areas on the UMRS. In contrast, commercial tows navigate only in the main channel and larger secondary channels connecting to port and fleeting areas. Because recreational boats travel closer to shorelines and in backwater areas, they can cause plant breakage and resuspension of sediments in shallow areas due to action of wake waves. The resuspended sediment and reduced underwater light can limit plant growth and reproduction. Recreational boats operating in shallow areas can directly damage aquatic plants with propellers, and the propeller jets can resuspend sediment. The focus of the study of effects of recreational boat traffic on aquatic plants was limited to the main channel borders, in order to assess the cumulative effects of this stressor in context with the effects of commercial navigation traffic. There was no attempt to estimate the effects of recreational boats operating in shallow backwater areas.

Screening for potential recreational boat wake wave impacts on plant breakage indicates that most potential plant growth zones in the main channel border areas are vulnerable. Figure 9-7 is an example map illustrating the potential plant growth zones in a portion of Pool 13 that receive recreational boat wake waves equal to or greater than 20 cm maximum height, and where breakage of aquatic plants may occur. Only wake waves from medium powerboats and large cruisers have potential for damaging aquatic plants in the main channel border areas. Wake waves from the other classes of recreational boats were lower and probably do not result in breakage of aquatic plants.

Figure 9-7. Recreational boat impacts on Pool 13 channel border habitats.



Impacts on plant growth were estimated by interpolation and using the results of the impacts of commercial traffic on plant growth. Specifically, maximum growth of plants is assumed to occur under conditions of zero sediment resuspension from traffic. Using the recreational boating traffic forecast, the sediment concentrations associated with the maximum traffic impact for cells in each pool were simulated. For each of these maximum effect cells, the corresponding estimates of live and total biomass plant growth were obtained for the 50th-percentile sediment concentration and 1-meter water depth using the same plant growth models used to assess the effects of commercial traffic (see Appendix ENV-H). Two elements allowed estimation of the plant growth that would occur as a result of the traffic from each vessel type, in each navigated area polygon, and in each zone of a given pool: 1) using the sediment concentrations and plant growth model results for each of the two plant species, wild celery and sago pondweed, available for each pool between UMR Pool 4 and Pool 13; and 2) the assumption that an inversely linear relationship between plant growth and sediment concentration is valid. A GIS database of estimates of total (live and dead) plant biomass reductions due to sediment resuspension by recreational traffic was developed, in conjunction with the navigated areas GIS.

Pool-wide impacts on plant growth from each vessel type were then estimated using a weighted averaging scheme that used the areas and number of navigated areas polygons with high, medium, and low traffic intensities and identified impact areas in buffer zones around each polygon.

Recreational boating traffic by large cruisers on the UMRS is predicted to produce the most sediment resuspension and suppression of growth for both wild celery and sago pondweed. Tables of plant growth reduction estimates are provided in Appendix ENV-J. The greatest estimated impacts on the growth of wild celery are predicted due to large cruisers in the main channel border areas of Pools 4, 7, 8, 9, and 10, with nearly a 100 percent decrease in growth. Suppression of wild celery growth by large cruisers is predicted to be significant in most of the other pools as well. Large cruiser traffic is estimated to exert the most impact on the growth of sago pondweed in main channel border areas of Pool 10, again with nearly a 100 percent decrease in growth. It is estimated that large cruiser traffic would also have severe impacts on the growth of sago pondweed in the main channel border areas of most of the other pools.

Medium powerboats are predicted to exert the most impact on the growth of wild celery in Pools 4, 6, 7, 8, 9, 10, and 11, with more than a 60 percent decrease in plant growth. Wild celery growth is predicted to be significantly decreased in most of the other pools from the passage of medium powerboats. Medium powerboats are predicted to exert the most impact on the growth of sago pondweed in Pools 9, 10, and 11, with more than a 60 percent decrease in growth. Sago pondweed growth in most of the other pools is also predicted to be significantly affected by medium powerboat traffic. Fishing boats are predicted to exert the most impact on the growth of wild celery in Pools 4, 8, and 10, with nearly a 10 percent decrease in growth. Fishing boats are predicted to have the most impact on the growth of sago pondweed in Pool 10, with about a 5 percent decrease.

Because they usually generate low-amplitude wake waves, passage of houseboats, jet skis, and pontoons is not likely to suppress the growth of aquatic plants in UMR Pools 4 through 13.

These results indicate that the risk assessment models are conservative, because some submersed aquatic plants persist in the main channel borders of Pools 4, 7, 8, 9, and 10 where recreational boat traffic is high and the models indicate near complete suppression of plant growth due to sediment resuspension. Although sediment samples were obtained and analyzed in the main channel border areas, sediment types are not homogeneous in the channel border areas, and some areas have sediment that is resistant to resuspension (sand without much fines).

Submersed aquatic plants that grow in the main channel borders of the UMR tend to occur in different growth forms (small mounded patches) than the extensive beds in backwater and impounded areas (McConville et al. 1998). These patches are resistant to current and may also be more resistant to the hydraulic stresses imposed by navigation traffic than plants growing in areas without much wave action and current. These patches trap sediment and result in mounds that elevate the plants above the surrounding substrate, enabling them to obtain more light than plants growing in deeper water. This growth form, once established, may allow submersed plants in the main channel borders to grow in more turbid conditions.

The results also indicate that wake waves and sediment suspended by recreational boat traffic are significant stressors on submersed aquatic plants in the main channel borders of the UMR.

9.1.2.15.5.2 Effects on Fish

Recreational boats operate at higher speeds and can kill fish by direct impingement with propellers. Fish that swim near the surface in channel areas, such as gars and paddlefish, are at greatest risk. Although no studies of fish mortality induced by recreational boating traffic have been conducted, paddlefish in the UMRS are found with wounds indicative of recreational boat propellers (S. Zigler, U.S. Geological Survey, Biological Resources Division, La Crosse, WI, personal communication).

Fish eggs, larvae, and juveniles can be killed by entrainment through recreational boat propellers and jet pumps. The impact mechanisms include acceleration/deceleration, change in pressure, shear, and direct impingement of fish on propellers. The stresses imposed on fish eggs and larvae and juveniles entrained in the propeller flow include acceleration/deceleration, change in pressure, shear, and the potential for direct impingement. These hydraulic stresses and potential for impingement on fish entrained through recreational boat propellers are probably greater than on fish entrained by commercial vessel propellers (see Sections 8.5.1.1.1, 8.5.1.1.2, and 8.5.1.2.2) given that recreational boat propellers are much smaller and rotate much faster than propellers on towboats. The percent survival of fish eggs, larvae, and juveniles entrained through recreational boat propellers is probably lower than the survival of fish entrained through towboat propellers.

Table 12 Appendix ENV-J summarizes the amounts of water estimated to be entrained by six classes of recreational vessels for the impounded reaches of the Upper Mississippi River and the Illinois Waterway for the April–August recreational boating season. Importantly, many UMR-IWW fish species spawn during this period. Entrainment volumes were estimated for recreational traffic intensities for the baseline year 2000 and the year 2040. Corresponding summaries were developed for volumes entrained by commercial vessels (Table 13 Appendix ENV-J).

Examination of the estimates summarized in Table 13 suggests that recreational vessels entrain a water volume equal to approximately one-third (0.32) of the volume entrained by commercial vessels navigating the Upper Mississippi River in the year 2000. The recreational vessels entrain nearly one-sixth (0.15) of the volume entrained by commercial vessels on the Illinois Waterway. In the year 2040, the corresponding fractions are 0.34 for the Upper Mississippi River and 0.12 for the Illinois Waterway. These results indicate that recreational vessels appear to entrain volumes similar in magnitude to volumes entrained by the commercial vessels on the UMR-IWW. These results also suggest that corresponding rates of fish entrainment mortality induced by recreational boating traffic may be a stressor of similar magnitude to fish entrainment mortality induced by commercial vessel traffic.

9.1.2.15.5.3 Effects on Mussels

Recreational boats can affect mussels and other macroinvertebrates through scour by propeller jets and by wake waves and sediment resuspension. Recreational boats on the UMRS have relatively shallow draft and may disturb only limited areas where mussels occur. Shallow areas along beaches are most frequently scoured by recreational boats as boaters apply power to beach their boats and depart from shore.

9.1.2.15.5.4 Effects on Wildlife

Recreational boating activity can have a variety of effects on wildlife (Liddle and Scorgie 1980; York 1994). The visual presence and sound of recreational boats causes fright-flight reactions in fish, birds, and furbearers. The degree of disturbance and energetic costs depend on the species, time of year, and the acclimation tolerance to boating traffic. Large aggregations of migrating waterfowl can be flushed by recreational boats, at a potentially large energetic cost to individuals. The flushing distance seems to be variable, depending on the species and time of year. Prescriptive and voluntary refuges have been established in a number of areas frequented by migrating waterfowl along the UMRS to limit disturbance by recreational boaters. Nesting birds along the river, such as ospreys and eagles, exhibit behavioral indications of disturbance when recreational vessels approach too closely. Increased suspended sediment in near-shore zones reduces feeding efficiency and increases energetic cost of foraging for sight-feeding fish and for fish-feeding birds. Reduced growth of submersed aquatic plants due to sediment resuspended by recreational boats limits food and cover for fish and waterfowl. Intensive beach use by recreational boaters probably limits nesting habitat and nesting success by turtles.

9.1.2.15.5.5 Effects on Water Quality

In addition to the sediment resuspension by boat wake waves described above, recreational boating traffic affects water quality by release of nutrients from the resuspended sediment (Moss 1977; Munawar et al. 1991; Yousef et al. 1978; Yousef et al. 1980) and from the release of unburned fuel and combustion products into the water (Schenk et al. 1975). Two-cycle outboard engines discharge as much as 30 percent of fuel used unburned into the water, along with combustion products. The advent of unleaded gasoline, and significantly more efficient and cleaner-burning outboard engines, has reduced discharge of petroleum products from boat engines.

9.1.2.15.6 Social and Economic Effects of Recreational Boating Traffic

9.1.2.15.6.1 Recreational/Commercial Traffic Conflicts

Early recreational boating on the UMRS consisted of either muscle- and wind-powered craft or larger excursion vessels. The powerboat segment has grown considerably in the last two decades. Conflicts between recreational boaters and commercial navigation exist, with respect to lockage, navigation safety, and aesthetics.

9.1.2.15.6.2 Use of Locks

A correlation analysis of conflicts for lockage between recreational and commercial vessels, using lock performance monitoring system (LPMS) data (USACE 1999a), found that the greatest lockage delay times for commercial tows occur at locks with the highest commercial traffic and the lowest recreational traffic. Locks with the most recreational boat traffic had low levels of commercial traffic delay. These sites also appear to more efficiently lock recreational boats, as measured by the number of boats per lockage. The study concluded,

> "*Based on data trends, correlation analysis, and recreational craft lockage capacity, it does not appear that there are significant conflicts between commercial and recreational users of the UMR navigation system which result in increasing commercial delays*."

9.1.2.15.6.3 Navigation Safety

Large rivers such as the Mississippi and Illinois Rivers can pose significant safety hazards to recreational boaters. The fast currents and eddies in the main channel take many inexperienced boaters for unexpected rides. Woody debris and snags are always present. Recreational boaters can collide with the locks and dams and with the submerged wing dams. The "backrollers" in the dam tailwaters are hazardous to boaters who enter the restricted safety zones below the navigation dams. Moored barges and unlighted channel buoys are hazards to recreational boaters operating at night. Towboats pushing barges are faster than they appear, and pilots have limited ability to rapidly stop or turn. Many recreational boaters do not take appropriate action to yield the right-of-way or to pass tows safely. Incidents with intoxicated boat operators are unfortunately common. Many new boat owners purchase larger, high-speed boats and operate them with little training or experience. Despite the increased efforts of States, counties, and the Coast Guard to improve water safety, these situations result all too often in recreational boating accidents, loss of property, and loss of life.

In examining documented recreational vessel accidents involving commercial craft, it was found that the incidence of such events is quite low, at least in recent years. The expected increase in both recreational and commercial traffic will probably result in some increase in accidents, but it is expected to be minor.

9.1.2.15.6.4 Quality of Experience

Commercial navigation on the UMRS is appealing to many, as indicated by the many visitors to the locks and dams, towboat "spotters," and the widespread interest in navigation history. But to others, these features, and commercial vessels themselves, detract from the aesthetic appearance of the river. Recreational boaters, particularly in smaller vessels, are justifiably wary of passing tows because of their deceivingly fast speed, looming bulk, the accompanying drawdown and wake waves along shorelines, and the powerful prop wash and standing wake waves. With a potential increase in commercial traffic, some users may perceive some further diminishment in the aesthetics of their river experience.

9.2 Baseline Condition for Cumulative Effects Assessment

In light of the stressors just described, their combined effects on the physical and ecological conditions of the UMRS, and the perceived resilience of the system in absorbing or adapting to these stress effects, it is now possible to describe a "baseline condition" against which to weigh the implications of incremental, commercial traffic-induced impacts. Description of this baseline also draws on the conclusions and recommendations of the WEST 2000 Cumulative Effects Study, as well as the Long Term Resource Monitoring Program (LTRMP) Status and Trends Report (USGS 1999).

9.2.1 Physical and Hydrologic Condition

The effects of the 9-Foot Channel Navigation Project have been well documented and will likely remain the subject of continued study and debate. Variability in stage has been reduced as more stable water levels are maintained to support commercial navigation. The species, habitat, and process implications of the loss of floodplain connectivity have been termed moderate to high on the Mississippi River and degraded on the Illinois River (USGS 1999). Construction of river training structures, which began in the late 1800s, has narrowed and deepened the channel and increased sediment deposition in channel border areas, with these effects being most evident in the lower pools and the open river. Levees have isolated the rivers from their former floodplains, and much of this floodplain area has been converted to agricultural use. The result of sediment deposition and levee construction has been a loss of off-channel aquatic habitat as well as floodplain forest, wet meadow, and overall terrestrial habitat diversity.

Overall sediment transport capability has been diminished, and sediment deposition has increased, particularly in off-channel areas and in the lower portions of pools. Sedimentation may, in turn, contribute to poor water quality through increased turbidity. A steady increase in population and concurrent development of the riverside environment has contributed to water pollution, particularly downstream of major metropolitan areas. However, increases in water quality have substantial positive effects in recent years. Sediment and pollution effects have been particularly detrimental on the Illinois River, although legislatively driven efforts to improve water quality (i.e., the Clean Water Act) have substantially improved this particular condition on both rivers.

Though sedimentation effects (at least in terms of new deposition) have decreased in the last 10 to 15 years, it is not projected that sedimentation will lessen as an issue on the UMRS, particularly on the lower impounded portion (below Pool 14) of the Mississippi River and the lower Illinois River. A concerted multi-agency effort, on a broad watershed scale, will be required to examine, address, and reduce the sources of sediment input. It will also be important to maintain habitat rehabilitation programs to restore and improve sediment-affected habitats. Sedimentation affects not only the amount of habitat, but also the diversity and quality of remaining habitats.

The system has, to some extent, reached an equilibrium point after initial post-impoundment improvements in some aspects and declines in other river conditions. By all measures of river health, the system currently exhibits a generally declined ecological condition. The degree of decline varies by pool or river reach, and it is generally agreed that the Illinois River has been most severely affected. This system still has the capacity to recover, as the Illinois River has to some degree (Theiling 1999). This has happened in certain portions or with certain species or habitats, most notably fish and some macroinvertebrate response to improved water quality, floodplain forest regeneration in the unimpounded reach, and vegetation response to experimental water level drawdowns (USGS 1999).

9.2.2 Ecological Condition

9.2.2.1 Habitat Condition

There have been general decreases in off-channel habitats and increases in main channel and open water areas, although this varies by pool or reach (WEST 2000). Above Pool 13, the Mississippi River still exhibits an island-braided form, with good aquatic habitat diversity. From Pool 16 and below, and into the open river, off-channel areas become scarcer, and thus aquatic habitat tends to be more uniform. Island loss is most pronounced in the lower portions of pools in some reaches. Dredging and dredged material placement cause primarily short-term impacts to aquatic and terrestrial habitats, and efforts have increased to conduct long-term planning for these activities such that habitat impacts will be minimized. The Upper Mississippi River System Environmental Management Program, Habitat Rehabilitation and Enhancement Projects (EMP-HREP) have been the most concerted effort to restore and enhance aquatic habitats on the UMRS. The Corps' small environmental restoration project authorities are also being used to address mainstem problems.

On the Illinois River, habitat conditions have historically been considered more degraded than those on the Mississippi River. As described in the previous section, sediment and pollution effects have been severe; water quality has improved somewhat over time. Very little contiguous off-channel aquatic habitat remains, and what does remain is greatly affected by sedimentation. A predominance of fine sediments exacerbates the problems of sediment resuspension and turbidity.

9.2.2.2 Species Populations

As described in Chapter 5, freshwater mussel populations have been adversely affected by a number of factors, including overharvest, pollution, siltation, and recently, the exotic zebra mussel. Mussel habitat for both lotic (flowing water) and lentic (still water) species has remained stable or increased above Pool 12, and decreased somewhat in Pools 13 through 26. Numerous site-specific mussel surveys have been conducted, but systemic data and monitoring remains incomplete, with the exception of some endangered species monitoring. The full impact of the zebra mussel on the native mussel fauna is yet to be determined, at least on a macro scale; the presence of zebra mussels has been documented throughout the UMRS, but large fluctuations in geographic distribution and density have also been noted. Commercial navigation traffic is one among several dispersal mechanisms for zebra mussels; continued monitoring and assessment of zebra mussel population dynamics will be necessary to fully evaluate the role of, and possible response to, commercial traffic in terms of zebra mussel dispersal.

For some fish species, the carrying capacity has likely been reduced as the result of decreases in the quantity, quality, or access to suitable spawning habitat, available food resources, or overwintering areas (overwintering habitat has been cited by some river biologists as a key limiting factor for fish populations). At the same time, some fisheries resources have increased in population abundance and diversity in response to diminished ecological stressors (i.e., contamination) (Lerzak 1995). Similarly, habitat restoration efforts (e.g., backwater dredging, fish nursery areas) and natural flood events (e.g., the 1993 flood) have demonstrated that substantial fisheries improvements can occur through enhancing and restoring habitat or recreating natural hydrologic conditions (Sparks 1995). The WEST (2000) study summarized historic changes and current conditions of fish habitat by guild.

Aquatic vegetation status varies by pool, but is currently abundant only north of Pool 14. Since impoundment, submersed vegetation has declined due to sediment effects, particularly in the lower impounded reaches of the Mississippi River and on the Illinois River. Wind fetch effects also have negatively affected some of the pools above Pool 14.

A large number of exotic and nuisance species have become established in the UMRS, and have been summarized elsewhere in this document and in WEST (2000). In some cases, these species have had a substantial impact on native populations of fish, plants, or invertebrates through competition for resources, displacement, or introduction of alien pathogens that harm native species. Common examples include purple loosestrife, Eurasian watermilfoil, the common or European carp, several other Asian carp species, and the zebra mussel. These species can be difficult or impossible to eradicate, and it is likely that they will persist into the indefinite future, with varying consequences for native flora and fauna.

9.2.2.3 Ecological Processes

Fragmented longitudinal connectivity caused by navigation dams has affected species movements; some dams form complete barriers to fish movement while others permit movement under only certain flow or operating conditions. Interruption of fish passage has geographically limited some populations. Processes described in Chapter 5 – water flow, material transport, habitat formation and succession, and energy flow and food web – have been variously affected as the UMRS has aged. Water flow has changed in response to the lock and dam system and levees; flows have become more uniform, concentrated in the main channel. Material transport capability has changed; the lock and dam system does not allow a free flow of materials and encourages deposition. Formation and succession of habitats such as islands and off-channel areas has been altered as erosional and depositional forces have been influenced by impoundment of the system. Finally, flow of energy has probably changed in response to changes in vegetation abundance and composition and changes in the hydrologic regime and distribution of surface water. All of these processes are dynamic and would likely change rapidly in response to changed environmental or hydrologic conditions.

9.2.3 Socioeconomic Condition

Overall, socioeconomic conditions on the UMRS have improved dramatically since construction of the Nine-Foot Channel Project. The advent of large-scale, relatively cost-effective transportation of bulk commodities has, in turn, caused an increase in agricultural, commercial, and industrial development on or adjacent to the system. From 1930, when the project began, to the mid-1970s, tonnage shipped on the Mississippi River increased 120-fold (Merritt 1984). The project also evolved into a vehicle for significant employment during the height of the Depression (O'Brien et al. 1992).

Within three major areas (agriculture, commercial, and industrial development), most sub-sectors are expected to gain in employment at least through 2010, with the exception of farming and manufacturing. Likewise, population growth is expected to continue at a modest rate on most of the study area, particularly in urban areas.

The rivers heavily influence the economies of their adjacent counties and States, providing benefits from a variety of river-related activities and supporting thousands of related jobs. At the same time, both large and small river communities have capitalized on their riverside locations to promote and develop recreational, tourism, and aesthetic opportunities. According to Brey et al. (2000), the actual market area for the UMRS extends well beyond the five States that encompass the project study area, to include a total of 30 States and 2 Canadian Provinces. However, within the five UMRS States, Illinois is forecast to receive the largest potential benefit from any alternatives that may be implemented, as all alternatives involve construction in that State and Illinois is already a heavy user of the river system.

9.3 Cumulative Impact with Project Alternatives

With any project improvements, and thus increased efficiency, more commercial traffic is projected to transit the system during the course of a year. The study environmental impact assessment has focused on assessing the effects to resources of concern of this projected incremental increase in traffic. Therefore, the cumulative impact assessment will center around the additive or synergistic effects of increased commercial traffic on the significant biological and cultural resources of the UMRS, using as a baseline the resource conditions described in the preceding section/paragraphs. These significant resources were also identified and described more broadly in Chapter 5, and evaluated for likelihood of direct and/or indirect impacts of navigation traffic in Chapter 8.

9.3.4 Physical/Biological Resources

9.3.1.1 Fish

The potential for direct mortality to individuals and indirect effects (e.g., habitat alteration) on population productivity contribute to the cumulative impacts on fish in the UMRS. Many, if not all, of the ecological stressors described in Chapter 8 affect fish directly, indirectly, or in combination. In evaluating the cumulative impacts on fish in the UMRS, broad-scale impacts to fish populations in general should be distinguished from more localized species-specific impacts. Larger-scale, systemic cumulative impacts may negatively influence the distribution, abundance, and diversity of fish populations throughout the UMRS. In contrast, species- or site-specific impacts may be confined to certain habitat types, sections of river, or guilds of species. In assessing cumulative impacts, it must be recognized that some stressors will negatively affect fish in general (e.g., severe pollution), while other forms of stress (e.g., conversion from lotic to lentic environments) might benefit some fish species, while other species are negatively affected.

The cumulative impacts of multiple stressors might reduce the carrying capacity for fisheries resources in the UMR-IWW System. These examples underscore the observation that stressed fish populations can respond rapidly to even short-term alleviation of specific stressors; as carrying capacities increase in relation to diminished stress, many fish can rebound quickly to realize these capacities.

The concept of “compensatory reserve” is important in understanding the potential cumulative impacts of multiple stressors on fisheries resources. Fish populations, in general, suffer high rates of mortality of eggs and larvae, yet these populations can remain in approximate equilibrium as each adult need only replace itself during its lifespan. Incremental increases in stress-induced mortality might be compensated by increases in survival of the remaining individuals, because of less competition for food, cover, and other factors. As long as fish losses are within this compensatory reserve, there will likely be little measurable effect on the adult population. Historical observations have demonstrated the rather sudden and catastrophic collapse of fish populations where mortality or reduced production capacity compromised the compensatory reserves (i.e., Lake Michigan lake trout, North Atlantic cod fishery). While this concept is widely accepted in fisheries management, it remains nearly impossible to quantify this reserve for any of the 140+ UMRS fish species or the UMRS fishery as a whole. Given the adverse economic and/or ecological consequences of drastic decreases in population sizes, the evaluation of cumulative impacts to fish and fisheries should be conservative in approach. Conservatism is also warranted by the sparse data and information available to assess cumulative impacts. With the continued operation and maintenance of the 9-Foot Channel Project, it is unlikely that main channel navigation characteristics will fundamentally change. Associated rock channel training structures will not decline in the future as a result of the proposed action. There are also no substantial adverse changes to fisheries proposed for routine channel operation and maintenance. However, the cumulative impact on main channel ichthyoplankton (i.e., fish eggs and larvae) can be expected to increase in proportion to anticipated increases in entrainment by commercial/recreational vessels and impingement and entrainment by the increased water demands of industrial/municipal water intakes.

The average annual incremental losses of future adult fish due to entrainment of fish larvae by commercial vessels have been conservatively estimated for 25 representative fish species, without project and for each of the six project alternatives (Section 4.5.1.1). The cumulative impacts over the 50-year project period (i.e., 2000 to 2050) of vessel induced loss of future adults have been similarly estimated for the six project alternatives. Large numbers of fish eggs or larvae found in the main channel planktonic drift include reproductive outputs that have been displaced from main channel borders or backwaters, the preferred spawning habitats of many fish species in the UMRS. These eggs and larvae would not likely survive regardless of possible entrainment by commercial vessels. To be consistent with a conservative evaluation of potential impacts, the entrainment of these eggs and larvae has been included in the overall assessment. In contrast, impacts to several species, including the freshwater drum, might be more substantial, because they spend most of their life history in the main channel environment.

The greatest potential for cumulative fishery impacts likely results from the continued degradation or loss of critically important habitat; for example, backwaters and secondary channels. A large number of the UMRS fish species depend on these areas for reproduction, early development, feeding, and overwintering; WEST noted three fish guilds that will likely be adversely affected by a continued loss of off-channel habitat. However, efforts in the last 10 to 15 years to restore or enhance critical off-channel habitats, including fisheries habitat, are expected to continue into the indefinite future. These programs will have some ameliorating effect on the impact of increased commercial traffic, which has the potential to exacerbate the degradation or loss of valuable fish habitat in the UMRS. Hence, the cumulative impacts of commercial traffic, added to other past, present, and predicted future stressors, may further diminish the longer-term diversity and abundance of fish in the UMR-IWW System.

9.3.4.2 Submersed Aquatic Plants

The two primary modes for cumulative submersed aquatic vegetation (SAV) impacts are from decreased light penetration due to increased turbidity levels (with resultant impacts to growth or reproduction) and physical damage resulting from increased water velocities. Wind- or vessel-generated waves can contribute to both the physical damage and sediment resuspension. The cumulative effect of land use/land cover, impoundment, and commercial/recreational navigation have collectively elevated the ambient turbidity levels such that SAV is scarce to nonexistent in the Illinois River and in the Mississippi River below Pool 13. Pollution is another factor that contributed to the virtual disappearance of aquatic plants on the Illinois River. Large areas of open water, particularly in Pools 7 through 10, exacerbate wind effects on plants as fetch lengths are increased. Loss or degradation of backwaters will also continue to limit the abundance of SAV. As noted above in the section on fish, continued implementation of habitat rehabilitation and restoration projects will likely contribute to some increase in SAV populations, at least in managed areas. Also, recent data (in the last 3 to 5 years) indicate that modified farming practices have had a role in reducing sediment inputs, and this trend is also expected to continue.

The proposed action is likely to contribute to adverse impacts on SAV through sediment resuspension and wave action (i.e., impacts to growth and direct breakage; no impact was determined on reproduction via reduced tuber production). The effects of increased traffic will be experienced predominantly above Pool 13; traffic effects are not expected to be substantial below Pool 13, but continued investigations will attempt to determine the extent and distribution of SAV in Pools 14 through 19 and the potential for traffic effects in these pools. Long-term data on plant beds from four areas in Pool 19 indicates wide fluctuations from year to year, but generally the same trend for each area. In the 1980s, these data depict increases in bed area, followed by steep declines through the early 1990s, with gradual increases from 1993 to 1996. The recent trend likely reflects the effects of the 1993 flood. Pool 13 itself could be considered a “threshold” pool in terms of suspended sediment levels and the ability to support SAV. Thus, slight increases in plant impacts due to commercial traffic may cause this threshold to be exceeded, resulting in major losses of plant populations within the pool.

Diversity and abundance of submersed aquatic plants are affected by a variety of environmental and physical factors, and are subject to considerable fluctuation in space and time. Drought and flood effects have been well documented (Rogers and Theiling 1999). Given this natural variability, and the need for continued research and data acquisition on plant populations, increased navigation traffic is expected to continue to contribute an additional, albeit minor (especially in Pools 4 through 13 where predicted traffic increases are smallest), negative effect on an already stressed resource. Lack of an impact finding on tuber production and survival does not point to cumulative effects through reduced reproduction.

9.3.4.3 Mussels

Unionid mussels are perhaps one of the most heavily affected biological resources found within the UMRS. Their overall abundance and diversity have generally declined by more than 50 percent in the last century. Their dramatic decline is primarily a result of their sensitivity to numerous stressors, especially pollution, impoundment, and exploitation. Several of these stressors will continue to threaten the viability of the UMRS mussel resource; indications are that the relatively recent introduction of the exotic zebra mussel will likely add to this threat.

Laboratory and field investigations conducted for the mussel impact assessment concluded that the proposed action is unlikely to contribute to additional adverse impacts on mussels.

9.3.4.4 Other Macroinvertebrates

The macroinvertebrate fauna consists of a variety of life forms and habitat requirements. Some groups prefer rock substrates, others are bottom-sediment dwellers, while others are closely associated with aquatic vegetation; within each of these broad groupings, further habitat specificity can occur (Sauer and Lubinski 1999; WEST 2000). Data on macroinvertebrate populations is very limited; systematic sampling of these organisms (fingernail clams and burrowing mayflies) only began with the LTRM program in the early 1990s, so long-term trends are difficult to determine on a widespread basis. Data compiled from 1992 to 1998 show a clear preference of the two study species for non-channel habitats, and total densities were consistently highest in Pool 13. Somewhat long-term data (yearly collection since the early 1970s) from Pool 19 has indicated wide fluctuations in macroinvertebrate populations, and evidence that extreme weather events, and related hydraulic conditions, have affected these fluctuations (Sauer and Lubinski 1999). In other pools, and particularly on the Illinois River, pollution has likely been a major factor affecting macroinvertebrate populations.

Based on a literature review and assessment of potential impact mechanism related to tow passage, it was determined that navigation traffic would have a negligible impact on macroinvertebrates. In the future, it is expected that continued improvements in water quality will benefit macroinvertebrates, and some preliminary studies of innovative channel training structures have demonstrated benefits in terms of benthic invertebrate species richness.

9.3.4.5 Waterfowl

Waerfowl populations in general, given their migratory nature, can be affected by a wide range of factors, many quite external to the UMRS (e.g., habitat conditions on breeding or wintering grounds, harvest pressure and regulation). The UMRS is a major flyway for migratory waterfowl, and some species also breed in the system; for example, the mallard, wood duck, and hooded merganser.

Diving duck use of the system is determined in large part by aquatic plant and macroinvertebrate distribution and abundance. Diving ducks have historically been most abundant in Pools 5, 7, 8, 9, 13, and 19; a strong relationship between scaup (*Aythya marila, A. affinis*) numbers and fingernail clam (*Musculium transversum*) abundance has been observed in Pool 19 (USGS 1999). Divers can be found frequently in open water areas in and adjacent to the main channel. Future abundance of diving ducks will be determined in part by the occurrence of suitable aquatic vegetation, particularly tubers, which are another preferred food source. Dabbling ducks also rely on aquatic vegetation (more so emergent species) and invertebrates and are found more often in off-channel areas and backwater lakes. Dabbling duck populations generally decline on the lower pools as off-channel areas become scarce. On the Illinois Waterway, waterfowl populations in general have been adversely affected by losses of aquatic plants and invertebrate populations; duck numbers have remained relatively depressed, with dabblers virtually absent, and divers estimated at about 500,000 birds (Theiling 1999).

The navigation impact analyses considered hazing or other disturbance as the only potential traffic-related impact mechanism for waterfowl. It was concluded that no appreciable impact would occur to waterfowl from the potential increased passage of commercial vessels. Projected increases in recreational traffic, particularly as they may affect off-channel areas, could pose more of a disturbance threat to waterfowl in the future. Unpredictable factors outside the UMRS, primarily habitat-related, will continue as the primary influence on waterfowl populations, and it is not expected that incremental increases in commercial navigation traffic will add directly to cumulative impacts. However, traffic effects on plant populations could indirectly affect waterfowl through denial of habitat and food resources.

9.3.4.6 Backwaters and Secondary Channels

Sedimentation is the primary stressor that contributes to the declining health of these two important UMRS habitat types. While land use/land cover changes and impoundment largely influence the sediment load and deposition rates, a number of factors can influence the conveyance or distribution of sediments within the various river reaches. Shoreline erosion and resuspension of sediments in and along the main channel by commercial or recreational vessels can potentially result in the remobilization of depositional material, which may subsequently be transported into sensitive backwaters and secondary channels.

Numerous investigations have examined sediment dynamics and budgets in the UMRS; WEST (2000) attempted to incorporate several of these, along with a comprehensive summary of historical planform data. The WEST study also developed a sediment budget. The information is much too extensive to repeat here, and the reader is referred to the original report (Volume 1). It is clear that significant areas of backwaters and secondary channels have been lost due to sediment deposition since impoundment. These losses are most pronounced in the Mississippi River pools below Pool 13, and on the entire Illinois Waterway. However, in summarizing their results and those of several past studies, WEST (2000) noted a definite downward trend in sediment deposition in backwaters.

Development of the UMRS for commercial navigation, starting in the late 1800s, originally aimed to maintain sufficient depth for vessels by concentrating flow in the main channel via the use of wing dams and closing structures. This practice continued along with construction of the locks and dams, and the presence of these structures has contributed to altered sediment dynamics and deposition into off-channel areas.

For most of their study reaches, WEST (2000) forecast that contiguous and isolated backwaters would continue to be lost through 2050. The only reach in which this was not forecast to occur was Pools 5 through 9, and this is due primarily to continued erosion of islands resulting in increased aquatic area. Consultation with UMR resource managers also identified contiguous backwaters and secondary channels as the two most prevalent areas of predicted future loss (USACE 2000a). The impact assessment for this study identified a total of 11 backwaters and secondary channels on the Mississippi River with a medium potential for impact from increased tow traffic; similarly, 20 such areas were identified on the Illinois River. The Illinois River is particularly susceptible to filling of off-channel areas due to its generally finer-grained sediments and narrow width. Given the documented historical loss of these areas, and forecasts of continued loss into the future, the predicted impacts due to tow passage are determined to have a cumulative impact to this important resource.

9.3.4.7 Floodplain Forest

The development of the UMRS floodplain for agriculture, and logging for fuel wood and lumber, resulted in widespread conversion of the historic forest/prairie mosaic. Today, this cover type is confined primarily to a narrow strip on the riverward side of agricultural levees. Species composition of the remaining forest has also become less diverse, due in part to altered hydrology, a loss of the seasonal "flood pulse", and the effects of periodic severe flooding, particularly the flood of 1993; this is especially evident in the decline of mast-producing species such as oaks and hickories. Bank erosion also has affected floodplain forests to some degree.

Habitat enhancement and restoration projects are increasingly including mast-tree planting components as a project future. These efforts, while worthwhile, are limited in nature; significant restoration of bottomland hardwood forests may not be possible without acquisition of large tracts of land and restoring connectivity with the river floodplain. These efforts are expected to continue into the future.

Potential impacts to floodplain forests were considered in this study as part of the bank erosion study component. Overall, a relatively small percentage of the existing floodplain forest was identified as possibly being at risk due to vessel-induced erosion. However, because of the importance of this cover type, identified sites would be further assessed as part of a project recommendation. Projected increases in commercial traffic, with project, are not expected to constitute a cumulative impact to this resource.

9.3.4.8 Air Quality

National recognition of the need to address air quality problems began in the 1960s, and resulted in passage of the original Clean Air Act in 1963, and its succeeding amendments. Ambient air quality, at least in rural areas and in most urban areas, remains generally good despite the degree of population growth and industrial and commercial development in the UMRS. Some large urban areas, notably Chicago, the Twin Cities metropolitan area in Minnesota, and the St. Louis metropolitan area, continue to exceed EPA standards for some criteria pollutants as of 1998 (see http://www.epa.gov/oar/oaqps/greenbk). Barge and rail transportation were brought under EPA regulatory authority with the 1990 Clean Air Act amendments. Tiered emissions standards are now in place for locomotives, and the EPA recently proposed rulemaking for commercial vessels.

Given that commercial vessel emissions are considered a small component in overall air quality, and that new emissions standards will be in place by approximately 2010 for these vessels, it is not foreseen that an increase in commercial traffic would pose a cumulative impact to air quality. The effects of a shift to alternative transportation modes, in the absence of waterway improvements, was addressed by Tolliver (2000).

9.3.4.9 Water Quality

As discussed earlier in this chapter, water pollution has constituted a major environmental stressor on the UMRS. Similar to air quality, historical disregard for discharge of pollutants into water bodies was recognized relatively recently, and addressed by landmark legislation that dramatically improved the UMRS, among many other degraded systems throughout the Nation. The Illinois River continues to exhibit degraded water quality, despite regulatory efforts, and the recent focus of concern throughout the system has shifted from point sources to non-point discharges. The cumulative effects of inadequately treated sewage and polluted runoff have been dramatically demonstrated in the hypoxic conditions in the Gulf of Mexico, the scope of which has become more apparent in the last 8 to 10 years (USEPA 2001).

Currently, water quality problems may arise on a site-specific basis, and similar to air pollution, problems tend to be most prevalent in the vicinity of major metropolitan areas. State and Federal regulations require municipalities and industry to meet strict guidelines, and with few exceptions, enforcement of these standards is strict. Along with the advent of Federal initiatives on improving water quality on a watershed scale (e.g., Clean Water Action Plan), it is expected that overall water quality in the UMRS will continue to show improvement in the future. Response to isolated spill incidents is under Coast Guard jurisdiction, and historically such incidents have been rare.

This study did not examine actual emissions from tows into the water, or disposal of garbage or other waste products. Such releases can emanate from both commercial and recreational craft, and in fact combustion by-products are more prevalent from recreational craft due to the relative inefficiency of their engines. From a cumulative impacts standpoint, this study examined the potential for increased hazardous spill incidents with a project, and concluded that there is little change in the risk of accidental spills with any of the project alternatives.

9.3.4.10 Land Use/Land Cover

Since impoundment, agriculture has been the major land use in the UMRS; the proportion of soybeans, as compared to other major crops, has gradually increased since that time (WEST 2000). This dominance is expected to continue into the foreseeable future. Increased emphasis on acquisition of floodplain lands for restoration purposes and nonstructural flood mitigation may reduce somewhat the proportion of land under production, but these changes may be balanced out by increases elsewhere. Any recommended plan under the navigation study will not pose a cumulative impact on land use/land cover; any site-specific construction impacts would be minor in scope.

9.3.4.11 Sedimentation

Mechanisms of sediment input, and the fate of these sediments, have been touched on in several of the preceding resource categories. The geomorphological development, basin and floodplain land use, and historic management of the Illinois River have resulted in a very high level of sedimentation effects; a low gradient, fine sediments, narrow channel, and main stem levees have all contributed to considerable loss of off-channel areas and silting in of backwater areas.

WEST (2000) found evidence that sediment inputs to the system have decreased since about 1950, due to improved agricultural practices and the construction of tributary reservoirs that trap sediments. The investigators also cited decreased dredging quantities since impoundment. Presently, sediment transport conditions were estimated by a budgeting exercise that considered a number of factors affecting input, storage, removal, and transport out of individual pools (WEST 2000). This exercise included the estimated backwater accumulation rates, and rates calculated from other studies, referred to in Section 5.2.3.1. Sediment loading from tributaries has decreased when comparing two broad time periods – post-impoundment to the mid-1950s, and mid-1950s to the present, and overall the sedimentation rate has decreased by at least a factor of two.

The dynamics of sediment transport, to some extent, remain unknown, and any trends and predictions can be upset by unpredictable events such as major floods or the uncertainty of future human activity in the watershed; thus the trajectory of the river and its floodplain, in terms of sediment accumulation and landscape change, remains somewhat uncertain (Soballe and Weiner 1999). The effects of navigation traffic, and the proposed project, do not directly affect sediment input and accumulation to the system; indirectly, an analysis of induced agricultural development indicated that the project would not cause appreciable increase in tilled land, and thus indirectly contribute further to runoff of sediments.

9.3.5 Social Resources

9.3.5.1 Population Characteristics

Following construction of the lock and dam system, many new residents migrated to the newly developed towns along the rivers. For the time period 1985-2000, population growth was fairly stable in the 78 counties along the rivers that comprise the study area. Current population projections indicate that growth will remain stable over the next several decades.

9.3.5.2 Public Facilities and Services
The lock and dam system is a public facility that has been used by both industry and recreation interests. Improving the system would temporarily affect the use of the locks and dams during construction; however, future impacts would be positive from maintaining this vital component of the national transportation infrastructure. Ecosystem restoration would ensure that the river system continues to provide opportunities for recreation experiences throughout the river corridor into the future.

9.3.5.3 Employment and Labor Force
Construction of the locks had a major positive impact on employment and the labor force, both locally and regionally. Daily operation of the lock and dam system draws from the labor force around the site-specific locations. Proposed construction activities for navigation and ecosystem improvements would likely draw on a regional labor force, increasing employment opportunities throughout the area. Future employment increases would be related to employment opportunities that would develop stemming from improvements to the navigation system or the ecosystem.

9.3.5.4 Business and Industrial Activity
Water access critically influenced business and industrial development. In early years, the rapid growth of population in the region greatly accelerated demand for manufactured products, which significantly increased local business and industrial activity. Following the years of major expansion, growth in business activity tapered off and has been stable over the past several decades. Future impacts would be related to community and regional growth, as well as to growth of the transportation industry and related businesses.

9.3.5.5 Farm Displacement
Initial construction of the lock and dam system likely affected agricultural land, as that was the basic land use along the river at that time. From time to time, agricultural land has been used for placement sites and staging areas during construction; however, impacts have been minor since the land was returned to its original use following project construction. Future navigation improvements are not expected to result in the loss of additional agricultural land or farmsteads. A potential for future farm displacement exists at locations that would require acquisition of floodplain acres for ecosystem restoration measures. The preferred ecosystem management and resroration plan identified a total of 105,000 acres of floodplain restoration over 50 years. This is approximately 10 percent of the levved floodplain.

9.3.5.6 Tax Revenues/Tax Base
A considerable increase in tax revenues from purchases being made for construction activities would have been experienced in the past. An increase or decrease in real estate value due to improvements at a site would change the tax base of a city and county; however, no appreciable changes are expected due to future improvements. Any long-term future impacts would be related to business and industrial growth.

9.3.5.7 Local Property Values
Changes in land use or zoning that affect property values and taxes have been minor following the completion of the lock and dam system. Long-term impacts would be related to community and regional growth and are undeterminable at this time.

9.3.5.8 Individual and Family Changes
Changes in daily living and movement patterns, social networks, and leisure opportunities as a result of the construction of the lock and dam system have been minor, and no significant changes in these areas are anticipated.

9.3.5.9 Regional Growth
The lock and dam system was a catalyst for significant growth of river communities and the entire Midwest region. Improvements to the navigation system and construction of the ecosystem restoration measures would provide positive impacts to regional growth that can be expected to continue into the future as a result of the direct and indirect effects of construction activity, expansion of existing firms, and establishment of new firms within the region

9.3.5.10 Aquatic Oriented Recreation
The lock and dam system has provided positive changes in the availability of this resource for leisure opportunity. Recr4eational vessel traffic is a significant component of total system traffic. Water-based activities dominate recreation use throughout the UMR-IWW, with over 12 million daily visits occurring in the most popular activities of boating, boat fishing, and sightseeing. These visits supported over $1.2 billion in national economic impacts (1990 price levels) and over 18,000 jobs nationwide. Overall, the ecosystem restoration alternative would have a net positive effect on UMRS ecosystem goods and services including aquatic oriented recreational opportunities. Recreational boating could be negatively affected by the water level management alternative, however, recreational boating would see and overall increase in benefits due to additional aquatic areas made accessible through alternative plan backwater and side channel restoration measures.

9.3.6 Cultural Resources
The systemic impact of increased commercial navigation on significant cultural resources has been determined to be bank erosion as a result of waves, drawdown, prop wash, and near-shore activity such as fleeting, temporary mooring, and barge terminals. Approximately 420,000 meters of potential bank erosion areas were evaluated for the Corps by Bear Creek Archeology (BCA) of Cresco, Iowa on the UMR and the Illinois State Museum Society (ISM) of Springfield, Illinois on the IWW. These investigations determined that there are 26 known National Register of Historic Places (NRHP) eligible archeological sites and 67 potentially eligible sites located adjacent to potential bank erosion areas. Bank erosion monitoring has been initiated at some of these sites and up to 50 meters of shoreline erosion has been documented to have occurred on or adjacent to the archeological sites over the last seventy years. It is anticipated that bank erosion resulting from increased commercial navigation will likewise increase and that the cumulative effect will be negative impacts to both documented and undocumented archeological sites.

The UMR and IWW project areas include NRHP eligible multiple property nominations for the Upper Mississippi River 9-Foot Navigation Project, 1931-1948 and the Chicago to Grafton, Illinois, Navigable Water Link, 1839-1945. The Upper Mississippi River 9-Foot Navigation Project 1931-1948 nomination recognizes 25 multiple property historic districts, delineates the district boundaries, categorizes the 158 contributing and 409 noncontributing resources within those districts, and defines architectural and engineering significance. The Chicago to Grafton, Illinois, Navigable Water Link, 1839-1945, nomination identifies 8 historic districts and 72 contributing resources within those districts. Site-specific measures will result in potential adverse effects to individual historic districts or contributing resources. These adverse effects will be treated in accordance with stipulations in the Programmatic Agreement (PA) in full compliance with the NHPA, however the cumulative effect of multiple site-specific measures and adverse effects may result in negative impacts to the NRHP eligibility status of the UMR and IWW multiple property nominations.

9.4 Summary of Cumulative Impacts
Based in large part on the cumulative effects assessment conducted for the Navigation Study by WEST (2000), and other sources, a qualitative assessment of potential cumulative effects was conducted for three major resource categories. The objective of this assessment was to consider, in accordance with CEQ

guidelines, the effects of the proposed action in light of all past, present, and reasonably foreseeable future actions. The period of assessment included the time period immediately following construction of the 9-Foot Channel Project up to the end of the Navigation Study planning period (2050). Numerous ecological stressors were evaluated in the context of their historical effects and contribution to the current state of the UMRS system. The assessment acknowledged the tremendous changes brought about by construction of the 9-Foot Channel Project, many of them negative, and in some ways still manifested today (Table 9-3and Table 9-4). Where significant cumulative effects are forecast, measures will be incorporated into the overall mitigation planning process to avoid, minimize, or mitigate for these impacts.

Table 9-3. Historic change in UMR planform features from pre-dam to post-dam periods (MC = main channel, SC = secondary channel, CB = contiguous backwater, IB = isolated backwater, AI = area of islands, PI = perimeter of islands, TOW = total open water).

Pool	Years	MC	SC	CB	IB	AI	PI	TOW
		acre	acre	acre	acre	acre	ft	acre
4	1930 - 1973	1,600	-75	5,508	277	-1,273	211,500	7,310
5	1930 - 1973	1,004	911	3,629	71	-1,638	194,900	5,614
5A	1930 - 1973	-208	504	1,579	232	-3,969	119,150	2,107
6	1930 - 1973	-210	414	634	1,215	-1,107	-2,200	2,053
7	1930 - 1973	83	5,185	1,376	129	-7,806	107,950	6,773
8	1930 - 1940	1,654	4,407	5,933	250	-8,070	845,580	12,245
9	1930 - 1973	462	9,444	3,835	42	-15,173	84,710	13,783
10	1930 - 1973	171	1,327	4,094	-95	-2,509	513,929	5,496
11	1930 - 1949	9,249	2,958	1,697	-690	-2,144	171,500	13,213
12	1930 - 1940	896	2,421	758	-390	-1,598	274,250	3,685
13	1930 - 1975	7,399	933	2,862	-977	-5,982	-353,200	10,216
14	1930 - 1940	601	182	1,525	-233	-139	323,000	2,075
15	1930 - 1937	-17	35	39	-3	-57	-16,000	55
16	1930 -1975	137	586	497	293	-1,512	37,800	1,513
17	1930 - 1940	40	184	191	232	-109	43,500	646
18	1930 - 1940	2,716	-835	1,550	105	-1,849	60,400	3,536
19	1930 - 1940	-2,853	156	-521	330	-257	68,180	-2,888
20	1930 - 1975	-871	195	-12	31	38	-3,650	-657
21	1930 - 1975	-434	-489	594	-101	-76	24,280	-430
22	1930 - 1975	-61	-479	151	18	-345	15,500	-371
24	1930 - 1989	-28	-552	438	380	368	84,250	238
25	1930 - 1989	61	-450	1,913	90	976	282,460	1,614
26	1930 - 1975	5,496	715	956	1,279	1,499	253,000	8,446
	TOTALS	**26,886**	**27,675**	**39,225**	**2,483**	**-52,731**	**3,340,790**	**96,270**

Table 9-4. Predicted change in UMR planform features from pre-dam to post-dam periods (MC = main channel, SC = secondary channel, CB = contiguous backwater, IB = isolated backwater, AI = area of islands, PI = perimeter of islands, TOW = total open water).

Pool	Years	MC	SC	CB	IB	AI	PI	TOW
		acre	acre	acre	acre	acre	ft	acre
4	1989 - 2050	-236	0	-1,021	-47	744	230,520	-1,304
5	1989 - 2050	362	-360	1,108	0	-647	-123,226	1,110
5A	1989 - 2050	84	-68	459	-3	533	35,589	472
6	1989 - 2050	84	-68	459	-3	533	35,589	472
7	1989 - 2050	88	-373	155	32	283	24,934	-98
8	1989 - 2050	889	-467	55	64	-2,541	-329,382	541
9	1989 - 2050	340	932	1,082	0	-2,025	-157,658	2,354
10	1989 - 2050	389	279	-1,316	123	-311	-178,393	-525
11	1989 - 2050	-1,973	-193	144	-53	60	-27,835	-2,074
12	1989 - 2050	295	0	-145	-4	-152	0	146
13	1989 - 2050	0	0	-62	-159	367	0	-221
14	1989 - 2050	0	0	-329	-59	0	-137,055	-388
15	1989 - 2050	0	0	0	0	0	0	0
16	1989 - 2050	192	266	-6	-87	0	40,070	365
17	1989 - 2050	0	-69	0	-53	77	4,200	-122
18	1989 - 2050	-361	0	-406	-38	287	28,070	-805
19	1989 - 2050	-1,165	-539	-250	-95	1,089	-70,190	-2,049
20	1989 - 2050	0	-55	0	-12	0	0	-67
21	1989 - 2050	-74	-323	-226	-11	0	0	-634
22	1989 - 2050	0	-91	-54	-14	0	0	-159
24	1989 - 2050	-105	-62	-33	-21	-100	803	-221
25	1989 - 2050	-174	-69	-42	-23	140	7,705	-308
26	1989 - 2050	-105	-404	-248	-385	0	0	-1,142
	TOTALS	**-1,470**	**-1,664**	**-676**	**-848**	**-1,663**	**-616,259**	**-4,657**

9.4.7 Biological Resources

Cumulative impacts were predicted for fish, submerged aquatic vegetation, and backwaters/secondary channels on the Mississippi and Illinois Rivers. With the exception of fish, these impacts are predicted to be minor; the proposed project would continue to contribute to an already degraded fisheries resource. In general, these impacts could be offset by an adaptive environmental restoration approach that focuses on the re-creation or enhancement of key processes (periodic drawdown, connectivity) and habitat features that have been degraded or lost.

Specifically, mitigation that focuses on perceived constraints on fish population size may be a useful approach to addressing potential cumulative impacts; estimating sufficient compensation for calculated direct impacts to fish may prove problematic, and an approach that emphasizes the enhancement of fish production and survival would address the effects of entrainment mortality and long-term population viability. “Systemic” measures such as improved fish passage at dams, alternative pool level management, and changes to navigation operations have been proposed to address direct navigation impacts; with appropriate monitoring and maintenance, these measures can also provide long-term benefits over the duration of the project life.

Submersed aquatic vegetation populations have been adversely affected by a number of factors, including commercial and recreational boat traffic. Additional traffic on the system is predicted to add to historic declines in SAV, and synergistically, could affect food and cover resources for other river organisms such as fish and invertebrates. Efforts to reduce sediment input from the surrounding watershed, in addition to mitigative measures such as island construction, revetments, and alternative pool level management, would likely benefit aquatic plant populations.

Vessel-induced resuspension and transport of sediments to off-channel areas was determined to be a threat to approximately 35 specific sites on the system. While a relatively small proportion of the total number of areas studied (just over 300), this predicted level of impact comes against a background of historic and current degradation and loss of off-channel areas. Ameliorative measures include reduction of sediment inputs, and protective barriers and/or restoration of degraded areas.

9.4.8 Social Resources

Nearly all socioeconomic factors evaluated would likely benefit from positive impacts in a cumulative sense. The acquisition of farmland for ecosystem restoration measures would have negative future impacts. Increases in noise levels during construction would be a negative future impact for both ecosystem restoration and navigation system improvements.

9.5 Ecosystem Sustainability in the Context of Cumulative Effects

The analysis and understanding of cumulative effects acting on the UMRS ecosystem presented above provided an important context for developing the ecosystem restoration alternatives. The documented historic change in land cover (habitat) diversity, resulting from cumulative effects, informed the creation of a virtual reference for ecosystem sustainability. The identification and quantification of habitat altering processes that will continue to affect the system in the future helped establish both the level and type of measures needed for ecosystem maintenance and restoration.

The adaptive implementation of a dual-purpose authority including the Ecosystem Restoration Alternative D’ framework will contribute significantly in offsetting the cumulative effects including the ongoing effects of operation and maintenance of the navigation project.